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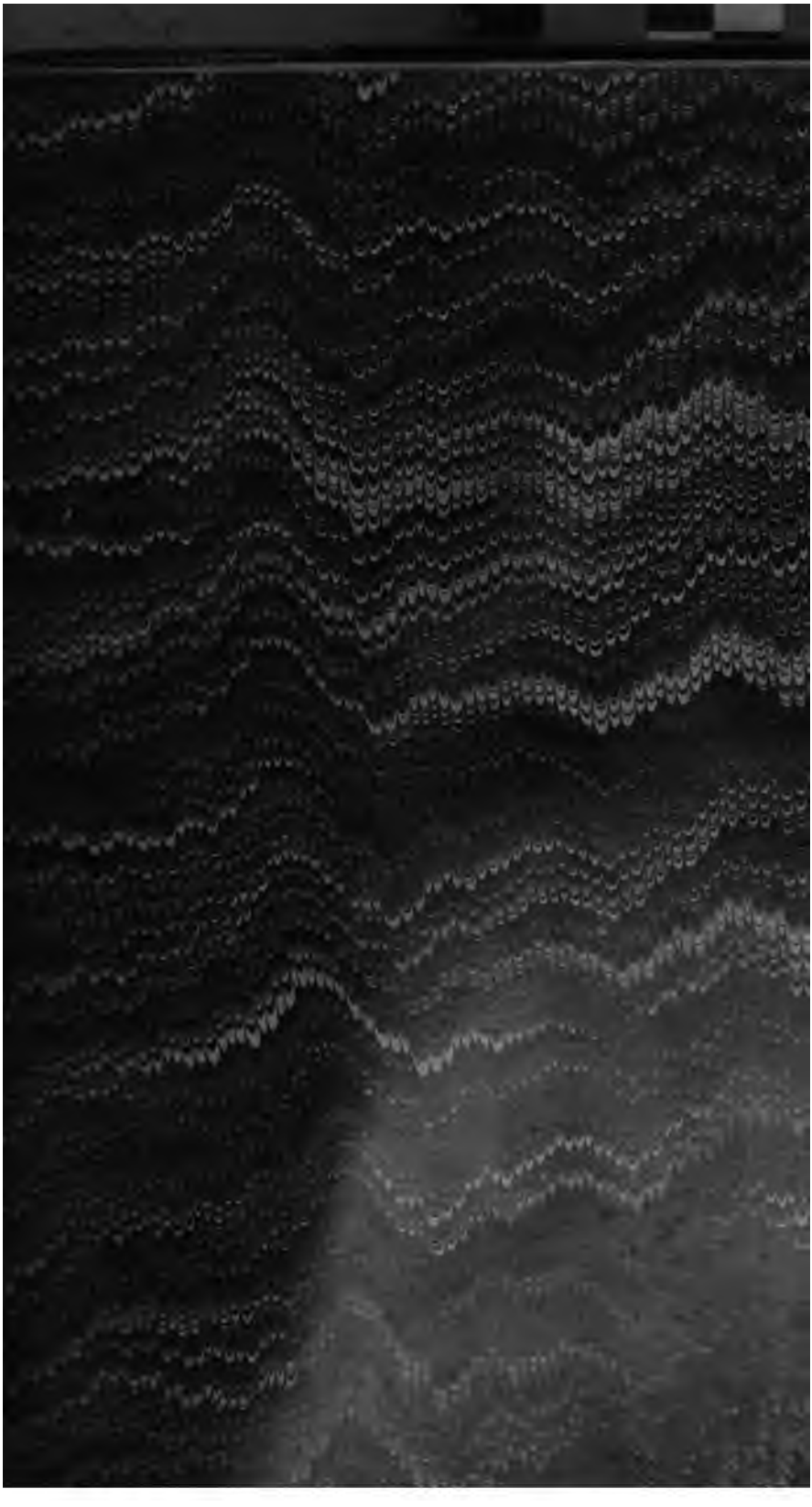
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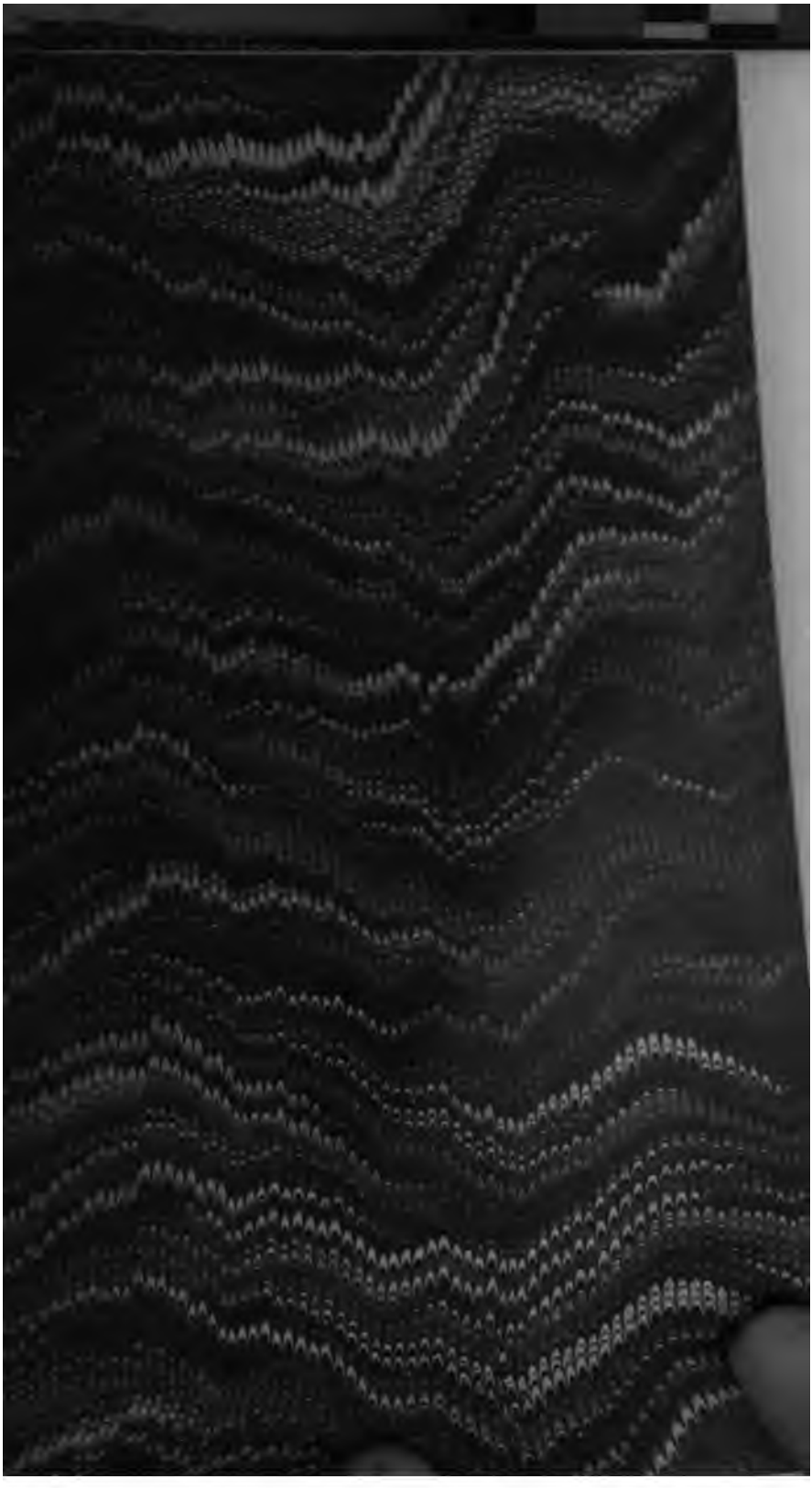














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THE

ROTHAMSTED MEMOIRS

ON

AGRICULTURAL CHEMISTRY

AND

PHYSIOLOGY.

BY

SIR JOHN BENNET LAWES, BART., D.C.L., LL.D., F.R.S., F.C.S., &c.
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13. Report of Experiments on the Growth of Red Clover by different Manures (Jour. Roy. Ag. Soc. Eng., vol. xxi., p. 178.) 1860

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AGRICULTURAL CHEMISTRY.

It is a matter of surprise that so little is actually known upon the theory of agriculture. Its practice is nearly coeval with mankind, while as yet it scarcely exists as a science. Ask the most experienced farmer to explain the principles which govern the routine he is daily in the habit of practising? Ask him to determine the value of any rotation of crops, or their comparative exhausting powers? Ask him what ingredients must be restored to the soil to keep its fertility unimpaired? or the exact manner in which climate influences his produce? His answers will be vague and unsatisfactory. But these, and a thousand other questions of a similar nature, are capable of solution by science, and they must be answered before agriculture can be said to rest upon a satisfactory foundation.

Independently of the money which must annually be lost in fruitless experiments, the disadvantages attending the want of fixed rules in agriculture are many. Numbers of men possessing capital are deterred from farming by the proverbial uncertainty of the profits attending it; and many who follow the profession of agriculture, and have the means, will not freely embark their money on the improvement of their farms, for want of that knowledge which would enable them to calculate their returns with any degree of certainty. Hence, too, the tenant farmer is frequently compelled to adopt a rotation of crops entirely prejudicial to his interest, retained only because it happened to be the custom of our ancestors a century ago, while the same rotation is enforced upon the farmer who expends 8*l.* an acre on his land, as upon him who expends only 3*l.*

Liebig's work on Agricultural Chemistry, published in the year 1840, attracted very generally the attention of British agriculturists. In those pages they were first made acquainted with the important aid they were likely to obtain from the science of chemistry applied to the cultivation of the soil. The work of Sir Humphrey Davy upon the same subject can hardly be said to have influenced the practice of agriculture. He applied the knowledge of chemistry, as it then existed, with his usual sagacity, but at the period in which he wrote organic chemistry was quite in its infancy. The labours of the German and French chemists during the last thirty years have principally been directed to the study of organic chemistry, which owes its present important position to the number of accurate analyses they have given to the world. It is much to be regretted that Liebig should have altered, in the third edition of his work, so many of the views and

opinions laid down in the first; or that a hasty visit to England, during which (as he says in his preface) he made himself acquainted with practical agriculture, should have caused him to pronounce as valueless the experiments of Boussingault, whose opinions are entitled to respect, as coming from one in whom are combined the scientific chemist and the practical farmer. Without entering into the merits of the different opinions maintained by these distinguished chemists, I may here observe that many of the errors into which Liebig has fallen, have, I think, arisen from his not sufficiently considering what agriculture really is. *Practical agriculture consists in the artificial accumulation of certain constituents to be employed either as food for man or other animals, upon a space of ground incapable of supporting them in its natural state.* This definition of agriculture is, I think, important, as distinguishing English agriculture at least from the system pursued in various parts of the world, where the population is small and the land of little value, viz., of taking only the natural produce of the soil, without any effort to increase it, and in time abandoning it for a soil as yet undisturbed. If Liebig had sufficiently considered this distinction, he would not have assumed that certain substances employed as manures are of little value, because plants and trees in their natural state, are capable of obtaining them in sufficient quantity for their use. The great problem to be solved with regard to manures is, what substances is it necessary to supply to the soil in order to maintain a remunerative fertility? The solution of this question appears easy enough, regard being had only to the composition of the crops removed. Practically there are, however, great difficulties attending it, which can only be entirely overcome by a long series of careful and costly experiments. If the ash theory advanced by Liebig, and so industriously propagated by his pupils, were founded on truth, a careful examination of the ashes of plants, and a few simple calculations upon the amount of mineral substances exported from the soil in corn, meat, &c., would at once enable us to explain and remedy the exhaustion of our soils. The farmer, when he sends his load of wheat to market, would bring back the few pounds of minerals which the wheat contained, and the return of these to the soil would enable him to produce the same amount of wheat for the market the following year. Unfortunately, however, the ground-work upon which this theory is raised is unsound, when agriculture, as distinguished from natural vegetation, forms the subject of consideration.

Agricultural plants, which practice has shown to differ widely from each other in their respective relations to soil, climate manuring, and position in rotation, possess at the same time widely differing powers of reliance upon the atmosphere for the

constituents which it is known to supply in a greater or less degree. If grain crops held the same relation to natural and artificial supply of their organic constituents, as the leguminous plants and turnips, the farmer would not require the assistance of the latter crops; but since, compared with these, the grain crops are in some important respects far more dependent upon artificial supply to the soil of certain organic constituents, of which the price is high and the supply limited, it becomes necessary to employ certain plants which possess the power of collecting these ingredients from the atmosphere, and such procedure constitutes a rotation of crops.

For some years past I have been engaged in a very extensive series of experiments upon my farm, with a view to determine some of the more important questions which are constantly arising in the minds of agriculturists. It would be impossible in a paper of this description to enter into a detail of the plan I have pursued in conducting these experiments. Keeping in mind the motto of the Society, '*Practice with science*,' I shall now merely select those results which bear most upon practical agriculture, and which appear to me most suitable to my present purpose. The greater portion of these experiments, and the various points of science connected with them, will be discussed with more propriety in an independent work. The views which I have adopted, and which I shall now endeavour to explain, have arisen during the course of these experiments; but it is very probable I shall have reason to modify them as the investigation proceeds.

I certainly place great reliance on the experimental results which I possess; every operation has been conducted under the eye of Dr. Gilbert, a gentleman who received his scientific education in the best British and continental laboratories, and has applied that accuracy which modern science demands, both to the operations of the laboratory and the field.

In the first place I shall offer some general remarks upon the growth and nature of the common agricultural plants, and afterwards endeavour to show the effect of manures upon them.

The crops which form a rotation belong, botanically speaking, for the most part to the three following natural orders of plants:— The *Gramineæ*, containing wheat, barley, oats, rye, and the grasses which constitute our natural pastures; the *Leguminosæ*, containing beans, peas, tares, lucerne, clover, trefoil, saintfoil, &c.; and the *Cruciferæ*, containing turnips and rape. The *Solaneæ*, yielding the potato, and the *Umbelliferæ*, carrots and parsnips may also be noticed. For the purposes of agriculture, however, a different system of classification might be adopted with advantage, having reference to the organ or part of the plant which is the object of cultivation. In clover, tares, and pasture, we generally require leaf and stem, which may be termed the primary

organs of plants; in the turnip we require the bulb or intermediate organ; and in the grain crops, peas, beans, &c., the ultimate organ, the seed.

In considering this subject it is necessary to bear in mind that the natural aim of every plant is to produce a perfect seed, and that, when growing in a soil and climate adapted to its special habits and peculiarities, it produces no more of each organ than it requires for the healthy perpetuation and reproduction of seed. When the leaf has fulfilled its office, the nutritious fluids circulating through it are withdrawn, and it decays or dries up. These fluids enter into the stem, and, rising higher and higher, are at length deposited in the seed. Plants are therefore required by agriculturists in two distinct conditions, one in which the nourishment is more or less circulatory, the other in which it is fully elaborated and deposited: in one case water constitutes above three-fourths of the weight of the produce; in the other it does not generally amount to one-fifth. Although the agriculturist possesses the means of developing the circulatory or elaboratory conditions of plants by manures and mechanical operations, climate exerts the greatest influence over them. By climate I mean the quantity of rain that falls, the number of days on which it falls, and the temperature during the period when the plant is actively growing or forming seed.

As the experiments to which I am about to refer were performed during the seasons of 1844, 5, and 6, I wish to make a few observations upon the climate of each season, and to show how the general condition of the crop was influenced by it. The temperature and fall of rain I have taken from the tables published by the Horticultural Society at Chiswick, from which my farm is little more than 20 miles distant, consequently the climate may be said to be nearly identical.

TABLE I.

Number of days' Rain during 30 wks. and 4 days.				Inches of Rain during 30 weeks and 4 days.			
	1844	1845	1846		1844	1845	1846
April . . .	7	15	18	April . .	0·33	0·99	3·84
May . . .	7	21	10	May . . .	0·26	2·88	1·35
June . . .	10	8	2	June . .	0·97	0·98	0·64
July . . .	10	21	16	July . . .	1·94	2·16	1·60
August .	16	21	17	August . .	2·00	3·32	4·82
September .	12	11	6	September .	1·27	1·68	1·39
October . .	19	13	24	October . .	4·19	1·48	5·50
	81	110	93		10·96	13·49	19·14

TABLE I.—*continued.*

Mean Temperature during 30 weeks and 4 days.				Mean Temperature above or below average.			
	1844	1845	1846		1844	1845	1846
April . . .	51·1	48·3	47·0	April . .	4 above	1·0 above	Averag
May . . .	54·2	49·5	55·7	May . . .	¼ below	1·8 above	3 above
June . . .	62·3	61·8	66·3	June. . .	2 above	0·9 below	6¼ above
July . . .	64·3	62·0	64·7	July. . .	1·6 above	0·9 below	2 above
August . .	60·4	58·9	65·2	August . .	2·2below	4·6 below	2·7 abov
September .	60 0	55·2	62·5				
October . .	50·2	51·2	52·7				
	57·5	55·3	59·1				

The season of 1844 was remarkable for bad crops of hay, clover, late-sown barley, and oats, very fine wheat with very short straw, and average turnip crop. In 1845 there was abundance of hay and clover, bad quality of wheat, abundance of straw, and one of the largest crops of turnips ever known. In 1846 the grass and first crops of clover were unusually abundant, wheat was of very fine quality, straw moderate, turnips deficient. Of course, there are plenty of exceptions to what I have stated, and these remarks do not apply to those places in which the climate varies much from that of London; but I have given what I believe to be the general character of the crops within a circle of 100 miles from London.

The soil upon which my experiments were tried consists of rather a heavy loam resting upon chalk, capable of producing good wheat when well manured, not sufficiently heavy for beans, but too heavy for good turnips or barley. The average produce of wheat in the neighbourhood is said to be less than 22 bushels per acre, wheat being grown once in five years. The rent varies from 20s. to 26s. per acre, tithe free. The fields selected for purposes of experiment had been reduced to the lowest state of fertility by removing a certain number of corn crops without applying any manure, and wheat and turnips were chosen for the subjects of investigation. The wheat-field consists of 14 acres, the crops removed since it was manured, barley, peas, wheat, oats. In 1844, the first experimental wheat crop was harvested, and the fourth is now growing. The turnip-field had not long been taken in hand, and was known to be in so poor a condition that it was at once put under experiment, and in 1843 the first crop of turnips was sown, and they have been continued each year since, the produce being removed and weighed. The wheat-field was divided into a certain number of equal spaces, of which one has been left unmanured, and one received 14 tons of dung every year; the remainder of the plots received different descriptions and quantities of artificial manures.

TABLE 2.

	1844	1845	1846
No. of Days' Rain during April and May (Grass Season)	14	36	28
No. of Days' Rain from May to end of August—17 weeks (Grain Season)	43	71	45
No. of Days' Rain from June to end of October—21 weeks (Turnip Season)	67	74	65
Inches of Rain during April and May (Grass Season)	0·59	3·87	5·19
Inches of Rain from May to end of August—17 weeks (Grain Season)	5·17	9·34	8·41
Inches of Rain from June to end of October—21 weeks (Turnip Season)	10·37	9·62	13·95
Mean Temperature during April and May (Grass Season)	52·6	48·9	50·5
Mean Temperature from May to end of August—17 weeks (Grain Season)	60·3	58·2	63·1
Mean Temperature from June to end of October—21 weeks (Turnip Season)	59·4	57·8	62·2
Temperature above or below average from May to end of August (Grain Season)	above 0·9	below 2·1	above 3·2

The above table gives the climate of the three years from the beginning of May till the end of October. I have considered the climate as affecting the grass to be that of April and May; wheat-climate to commence with May and end with August; turnip season to begin with June and end with October :—

It will be seen that the two spring months of 1844, April and May, were unusually dry; the quantity of rain and the number of days in which it fell were both small; the summer was hot and dry, and the autumn moderately rainy. An entire absence of the climate necessary for an enhanced accumulative and circulating condition of plants prevented the favourable growth of the spring crops, and a hot and dry summer favoured the depositing and elaborative condition, and produced good quality of grain. In 1845 the great number of wet days and the low temperature of the summer were highly favourable to a circulatory condition of the plant, consequently green crops of every description and straw were unusually abundant, and grain of bad quality. In 1846 the spring was very favourable to a circulating condition, producing luxuriant crops of grass and clover. The month of June, when the grain was forming seed, had a temperature 6¼° above the average, with only two days in which rain fell, and produced very fine quality of grain. The inferior crops of turnips obtained that year, notwithstanding the large total amount of rain, arose from the almost entire absence of rain for thirty-one successive days, twice during the season. From May 21st to *June 21st no rain fell,* and from August 22nd to September 21st

there were only three days' rain, amounting to less than one-tenth of an inch.

The following table indicates the effect of climate upon the quantity and quality of the produce of the unmanured plots of the experimental wheat-field (during three seasons); the average results of the variously manured plots are also given :—

	1844	1845	1846
Corn, per acre, in bushels, pecks, and quarters*	16	23	17. 3. 3
Straw, per acre, in pounds	1120	2712	1513
Weight of dressed corn, per bushel, in pounds .	58½	56½	63¾
Proportion of corn to straw (straw 1000) . .	824	531	797
Mean of all the plots—			
Weight of dressed corn, per bushel, in pounds	60¾	56½	63
Proportion of corn to straw (straw 1000) . .	868	499	765

The effect of the climate of these three seasons, as indicated in this table, is quite in accordance with the general character of those seasons. The lowest weight of the bushel and the greatest amount of straw were obtained in that season which had the greatest number of rainy days, and the lowest temperature; the least amount of straw with the driest season, and the finest quality of grain in the hottest summer. On comparing the proportion of grain to straw and the weight per bushel of the corn obtained from the unmanured space, with the average results of the various experiments, it will be seen how much they agree one with another, and this is the more remarkable as manures of the most varied kinds were employed, some of which doubled the natural production of the soil.

It is highly important that experiments should be tried in different parts of England, having reference to the effect of climate upon produce. A rain gauge and a registered thermometer is all the apparatus required. If half an acre of the different crops on a farm were carefully weighed, and the relation of corn to straw, leaf to bulb, and the quality of grain estimated, we should in a few years be put in possession of sufficient data to enable us to speak with certainty upon this subject. It would then be seen that each shower of rain and each change of temperature had an effect upon vegetation, which, when once ascertained, might always be calculated on. The farmer would be able to make an estimate of the quality and produce of his crops before a grain had been removed from his field. Even with the information obtained by a careful examination of the above table, it is hardly to be doubted that the farmers in Scotland and in the north and west of England can produce turnips of finer quality and at less expense than those who dwell in the middle and south of England, and that the farmer in the south of England can produce the best

* *1844 total corn, 1845 and 1846* dressed corn only.

corn. By the application of capital and skill an artificial climate may, to a certain extent, be obtained. I shall point out some of the means to be employed when speaking on the subject of manures. But where equal means are employed I think a farm upon which there are a certain number of rainy days in the summer and autumn possess advantages in the production of green crops over another farm upon which the average amount of rainy days is less; and, on the contrary, where the least number of rainy days and the highest temperature exist, corn of the best quality can be produced. The summer of 1846, with a mean temperature of more than three degrees above the average of the climate of England, having produced grain, weighing 63¾lbs. per bushel, upon any soil from which seven unmanured corn crops had been removed, proves undoubtedly that high quality of grain to a great extent is determined by climate independently of the action of manures. We should, therefore, expect that those countries enjoying a hotter and drier summer than our own would produce corn of superior quality, and such, indeed, is the case. In spite of the wretched system of agriculture which prevails in Spain, Russia, Poland, and Sicily, the quality of their corn will bear comparison with that which the skill and knowledge of the British agriculturist can secure. The climate of Australia combines in an eminent degree the small amount of rain and the high temperature necessary for the perfect development of corn, and the wheats imported from that island obtain a price in the market very much beyond those of English growth. The following table gives the average climate of Australia compared with that of London during the summer :—

	London.	Adelaide.
Number of days' rain in four months	60	19
„ inches „ „	8·49	3·88
Mean temperature „ „	60·	79 F

Although in producing good quality of corn the farmer labours under a disadvantage with regard to climate in England, its low temperature and moisture are exactly suited for our turnip crops, and the advantage which he derives from this plant more than counterbalances the inferior quality of his grain.

We now arrive at another important question—What is meant by quality of wheat? Does it depend upon the weight per bushel, or specific gravity of the grain? and if so, does this specific gravity bear any relation to the per-centage of gluten and albumen; that is to say, to the most highly nutritive constituents of the grain? Before entering into a consideration of this subject it may be as well to state the opinions generally held regarding it. The grain is composed of a variable proportion of protein com-

pounds, gluten and albumen; and carbonaceous compounds, comprising starch, sugar gum, oil, &c. The protein compounds are employed in the organism of man and other animals in forming flesh, while the carbonaceous compounds supply heat and form fat. The protein compounds being of much the greatest importance to the animal economy, it has been generally supposed that the value of different descriptions of wheat depends upon the amount of gluten and albumen which they contain; that the wheats of hot climates contain a greater proportion of these substances than our own; that for this reason the miller purchases them at a higher price; and that by employing rich manures the farmer is enabled to increase the per-centage of gluten in his corn. To the agriculturist it is of little importance that his wheat is rich in protein compounds, unless they increase its value in the market. Now millers, who are his principal customers know nothing about gluten and starch; they judge by the eye alone, and give the highest price for that which will yield the greatest proportion of flour. The following table demonstrates that the value of different samples of wheat does not depend upon the per centage of nitrogen which they contain.*

Nos.	Season.	General Remarks upon the History of the Specimens.	Per Centage of Nitrogen in Dry Matter.	Price per Qr. according to *present* rates adjudged by Miller and Corn Factor.
				s.
1	1844	Grown by Superphosphate of Lime . .	3·03	84
2	,,	As No. 1, with ammonia Salts	2·65	86
3	1846	Liebig's Patent Manure	1·81	96
4	..	As No. 3, with Ammoniacal Salts . . .	1·69	92
5	,.	As No. 3, with Rape Cake	1·89	88
6	,,	As No. 3, with Rape Cake and Ammoniacal Salts.	1·88	...
7	,.	Exhausted Soil, Unmanured.	1·95	92
8	,,	,, ,, with Ammoniacal Salts	2·01	92
9	,,	,, ,. with Rape-cake . . .	1·85	92
10	,,	,, ,, with Rape-cake and Ammoniacal Salts	1·93	92
11	,,	Australian, No. 1	...	112
12	,,	,, No. 2	1·94	112
13	,,	,, No. 3	2·38	112

From this table it is evident that the samples of wheat most approved by the miller are by no means those which are richest in nitrogen. His choice is directed to those samples which have the character of a perfectly developed grain, small, plump, and thin-skinned. But laying aside the evidence of experiment or

* The wheat employed as seed in these experiments was the Old Red Lammas; nearly 2 bushels were drilled per acre. The crops of 1844 and 1846 were sown in September, and that of 1845 in March.

common usage, would it not be more consonant with general principles to suppose that a class of plants proverbially characterized as yielding starchy seeds, and whose predominant peculiarity it is to produce carbonaceous substances, should, in their most perfect state of development, be rich in starch rather than in gluten and other nitrogenous compounds? We might, indeed, expect to find the proportion of gluten and starch vary in different species of wheat, and in the same species under the effect of different climates and seasons; but the more perfectly the grain has been developed the richer in starch and the poorer in nitrogen it would become, and millers who prefer a perfectly developed grain probably pay the highest price for that which contains the most starch.

That the gluten and albumen in wheat would increase in proportion to the richness of the soil and to the amount of nitrogen and ammonia supplied in the manure seems so reasonable a supposition that its correctness is admitted without dispute; and various experiments have been tried which appear to favour this opinion. Boussingault, in his 'Rural Economy,' says, that wheat planted in an open field gave 2·29 per cent. of nitrogen, equivalent to 14·31 per cent. of gluten and albumen, while that planted in a rich garden soil gave 3·51 of nitrogen, or 21·94 of gluten and albumen; and Hermstadt obtained from wheat grown—

In a soil unmanured . . .	9	per cent. of gluten.
In a soil manured with cow-dung .	12	ditto.
,, sheep ditto .	22·9	ditto.
,, bullock's blood	35	ditto.
,, urine . .	36	ditto.

It is not stated how the gluten and albumen were determined, but it is not improbable that some mechanical process was employed; at all events, I have great doubts about the accuracy or the completeness of the experiments. Thirty-five per cent. of gluten would be equivalent to nearly 6 per cent. of nitrogen, a quantity certainly greater than wheat ever contains. My own experiments do not give the slightest indication of an increase in the percentage of the nitrogenous constituents of wheat grain by the employment of ammoniacal manures. That the acreage produce of nitrogen in the crop bears a certain relation to the ammonia supplied in the manure is very evident; but the per centage of nitrogen in the grain cannot be increased by means of it. In some experiments, the quantity of ammonia supplied by the manures was from 60 to 70 lbs. per acre, and in some instances more; but the analyses give no evidence of an increased per centage of nitrogen by its supply, and the highest amount obtained in the series was from an experiment where no ammonia was supplied in the manure.

Dr. R. D. Thomson, in his "Experimental Researches on the

Food of **Animals,**" says, "It is a sufficiently remarkable fact, that oats increase in nutritive power in proportion to the increase of latitude within certain limits, while wheat follows an inverse law." He seems here to have adopted the prevailing opinion that the finest descriptions of wheat contain the most nourishment. The oat, which is capable of thriving in a moister and colder climate than either wheat or barley, would undoubtedly contain more nourishment when grown in high latitudes, simply because the climate is not favourable to the production of the important carbonaceous compound of gramineous seeds, starch. But with the most favourable condition of soil and climate the grain-producing plants are undoubtedly governed by one and the same law.

Although I have not at present traced the changes which take place during the growth of wheat, it appears to me that when sown in a soil containing abundance of azotized matter it employs this substance at first in extending its leaf, and that where an excess of ammonia is supplied the production of leaf is increased to an extent greatly injurious to the next operation of the plant, which is to produce stem. If an excess of ammonia is added late in the spring the plant will no longer increase in leaf, but in stem or straw, which also may be increased to an injurious extent. When the azotized and mineral matters are properly balanced, the plant will produce no more of each organ than is essentjal to the favourable production of its seed. Up to the period of blooming the compounds of nitrogen derived from ammonia are probably in a fluid or suspended state, circulating through the whole of the plant; but to what extent starch exists in the plant at this period is doubtful. When the time of blooming is passed, it is probable that the wheat derives but little nourishment from the soil, at all events, if a crop shows symptoms of poverty, it is always before this period. The circulating condition which has prevailed throughout the plant, is now changed, and under a favourable condition of climate (heat, light, and dryness) an elaborative action commences; the compounds of nitrogen are withdrawn from the leaf and stem, and deposited in the seed, while starch is accumulated in a hard granular form. This deposit of starch only takes place perfectly under the influence of a high temperature; the seed is then hard, dry, and plump. In a cold and wet summer the interstices of the grain are not perfectly filled; watery fluids occupy the place of starch, and, when these have evaporated, the grain is thin and shrunk. The wheat that is grown in a wet summer might therefore contain as high a per centage of nitrogenized matters dependent on the sap as that produced during a hot and dry season. The formation and elaboration of starch and other carbonaceous compounds which for the most part supply man with his respiratory or heat-producing elements, are, it seems, greatly favoured by a hot climate, and it is

probable that the heat capable of being eliminated by the process of animal respiration, must first have been rendered latent during the growth of the plant.

Looking at the present state of man's existence on the earth, it may appear improbable that the value of corn should ever be in proportion to its carbonaceous product. A time may arrive, however remotely, when the surface of the earth will be peopled with men very far advanced both in their moral and physical condition, compared with its present occupants. Bread and meat will then constitute the chief sources of food—the one supplying respiration, the other nutrition; and they will doubtless bear a more philosophical relation to each other all over the world than at present. The system of cultivation in England may be considered as tending to such a result more nearly than that of most other countries, and if the principles which it involves were properly understood and carried out, we might become independent of foreign supplies, even if our population were much greater than it is now. I have before stated that the ammonia in a manure is employed by grain-plants to develop carbonaceous products: the same principle is apparent in the economy of animals. Dr. R. D. Thomson, in his experiments, found that the cow which received the largest amount of nitrogen in its food produced the greatest weight of butter; and the general experience of agriculturists ascribes the most fattening properties to those substances which contain the greatest proportion of nitrogen. Although ammoniacal manures favour the elaboration of carbonaceous matters in grain, we might expect to find a different result in examining the seeds of the leguminous plants. The peculiarity of these plants is to produce a seed containing a highly nitrogenous element, called legumen. In our own experiments we find grain in the driest state contains one and two, but rarely three per cent. of nitrogen. We find in the dry substance of clover-seed as much as 7 per cent., and in beans and peas 5 per cent. The proportion of nitrogen in the seeds of these plants would, therefore, probably increase, within certain limits, under the influence of ammoniacal supply. The following results obtained by Dr. Gilbert seem to favour this view :—

	Per centage of Nitrogen in Dry Matter.	
	Exp. 1.	Exp. 2.
Beans grown by mineral manure	4·77	4·78
Beans grown by ammoniacal manure	5·11	5·09

In the seeds of cruciferous plants, turnips and rape for ex-

ample, a non-nitrogenous product, oil, seems to abound, and we might expect that ammoniacal manures would tend to enhance its production in such plants, in like manner as that of starch is increased in the seeds of the gramineous family. Turnip-seed is not, however, cultivated in England with a view to its oily products, and I have only investigated the effect of ammoniacal supply upon the leaf and bulb of the plant.

In reference to the circumstances under which the formation of the special product of plants seem to be increased, a few remarks upon the cultivation of sugar-cane may not be out of place, especially as there are so many agriculturists in this country who possess property in the West Indies, and the application of scientific principles would increase the production of sugar and reduce the expense of its cultivation to an extent not very readily imagined. Although sugar is found in almost every plant at certain periods of its growth, it is only extracted profitably from three or four, of which the cane is the most important. Sugar belongs to a class of carbonaceous substances, all of which are developed in the greatest perfection in the hottest regions. Among these are starch, gum, and oil; and although each plant possesses organs necessary to perfect its peculiar carbonaceous products, the same laws must govern the formation of them in all. In wheat I have shown that the carbonaceous product, starch, increases with a supply of ammoniacal manures, under the influence of a high temperature and the absence of rain; owing, however, to the moisture of our climate, and the want of that temperature which is required for producing and depositing starch, there are difficulties in the way of increasing this carbonaceous compound, which would not be met with if the same principles were applied to produce sugar in the cane. If I could depend upon a constant climate in England similar to that of 1846, I could produce annually 40 or 50 bushels of wheat upon an acre with the same facility that I now produce 33 or 34; but as it is, were I to supply the proportion and quantity of mineral and organic manures necessary to produce 50 bushels, in a wet and cold summer—it would unduly develope the circulating condition of the plant, its vascular structure would be increased to an injurious extent, and the crop would be laid. Those who farm very highly have often experienced this misfortune, and consequently they dread a wet summer.

To the farmer whose land is out of condition, however, a wet summer is favourable, inasmuch as it increases the supply of those elements of which his crop is in need. In the sugar-cane the carbonaceous product is required in a circulating condition; therefore those substances should be applied as manures which increase the vascular action of the plant: at the same time the soil should be rendered as dry as possible by draining. In soils

where the elements of fertility exist naturally, or where they are properly supplied in the manures, the richest juice and largest amount of sugar would be produced in the driest season. In the absence, however, of the proper amount of organic matter in the soil, the vital actions of the plant would, under the same climate and circumstances, be weakened. The combustion of the cane for fuel is a process which cannot be too much condemned. It involves the necessity of a much greater outlay in manures every year; for, if the mineral matter which remains after combustion is restored at all to the soil, it is very much less efficacious than it would be if accompanied by the substance of the cane itself. In a well-regulated sugar plantation, non-nitrogenous products constitute the only export from the soil. The nitrogenous elements, which are rendered insoluble when the juice is heated, should be carefully removed, and either restored to the soil directly as manure or after being employed as food for animals.

The English farmer necessarily suffers an exhaustion of his soil from the removal of various ingredients which have not place in the constitution of sugar. In grain both nitrogen and phosphate are exported, both of which must be restored to the soil in due course. We hear of plantations which formerly produced many hundred hogsheads of sugar, now producing one-third the quantity. This can arise from nothing but exhaustion of the soil. It cannot be too generally known that the elaboration of carbon-compounds bears a very constant relation to the supply of ammonia in the manure. Every pound of sugar exported, and every pound of the cane which is burnt, involve the necessity of a supply of ammonia to the soil. Taking into consideration the immense advantage which a tropical climate affords, and the comparatively high price of the product, the cultivation of sugar offers advantages for the profitable employment of skill and capital greatly superior to any that our agriculturists can hope for. It would however, be injudicious and improper, in defect of actual experiments, to attempt to lay down rules in detail for the application of a principle regarding which, as such, little doubt may be entertained.

I now come to the action of manures, which are generally divided into two classes—*organic* and *inorganic*. Although this distinction is by no means satisfactory, I shall adopt it as being generally understood. Organic manures are those which are capable of yielding to the plant, by decomposition or otherwise, organic matter—carbon, hydrogen, oxygen, and nitrogen—constituents which uncultivated plants derive originally from the atmosphere. Inorganic manures are those substances which contain the mineral ingredients, of which the ash of plants is found to consist. Most

of the substances employed as manures contain both organic and inorganic substances. The greater portion of soils consist of minerals in a greater or less state of decomposition, combined with a small amount of organic matter. Every soil is capable of yielding a certain amount of vegetable produce under the influence of climate and season, without the assistance of manure: this may be called its natural produce. The proportion would vary each year, according to the amount of rain, the temperature of the season, and the description of the growing plant. It is known, however, that although the climate of any place may vary one year as compared with another, it nevertheless maintains a certain average. It may be supposed therefore that the natural produce of the soil, in any particular locality, would be uniform for a series of years.

The effect of rain is to dissolve a certain portion of the mineral matter of the soil: it also supplies carbonaceous matter and ammonia. Liebig found ammonia in the rain at Giessen. The rain collected in a vessel placed on the top of a tree in my wheat-field, at a distance from any building, gave, upon evaporation, a liquid having a fœtid smell, and yielding ammonia to suitable re-agents. The rain collected in a rain-gauge placed in a garden at Mamhead, in Devonshire, had the taste of soot, although the wind was blowing direct from the sea during its fall. Rain is therefore capable, to a certain extent, of supplying plants with ammonia. Carbonic acid is also a constant and important constituent in rain-water, as well as in the atmosphere itself. The atmosphere may thus be considered the natural source of organic, and the soil that of inorganic, supply. It is the object of agriculture to increase the produce of the soil beyond its natural yield, which can be done by various means. The field may be fallowed—that is to say, the natural produce of the soil for two years may be concentrated into one—the repeated exposure of the soil to the atmosphere, by means of ploughing, causing a decomposition of mineral matter, while the ammonia in the rain unites with the various acids in the soil. The produce of the soil may also be increased by means of manures—that is to say, by supplying those ingredients which the soil and the atmosphere are incapable of yielding in sufficient quantity for an agricultural result. This process I shall now endeavour to explain. It will be remembered that the produce of wheat and straw upon the unmanured portion of my experimental field was greatest in the year when the atmospheric influence, and therefore the supply of ammonia, was the most; but in no case was a full agricultural crop obtained. This may be attributed to two causes: either that the wheat was incapable of assimilating what the atmosphere and rain could supply, for want of an available amount of minerals in the soil; or that the minerals

in the soil were in excess, but that the wheat was incapable of assimilating them for want of a sufficient supply of ammonia, or other organic substances.

It has been argued by Liebig that the atmosphere can supply the ammonia from which plants derive their nitrogen, in sufficient quantity for agricultural purposes; and his views on this subject have been echoed through England by a host of his followers. This point, upon which so much difference of opinion exists between the French and German chemists, is perhaps the most important to agriculture which chemistry can solve. It affects the whole economy of cultivation, and the final solution of it must materially influence the actions of all practical agriculturists. With regard to the most important crop (wheat), my own experiments are so decisive, and through the whole series the results are so uniform, that it is hardly possible to have two opinions on the subject; and what is still more important, they are in accordance with the dictates of reason and the practical experience of agriculture. The first year's experiments were drawn out principally with the view of ascertaining how far mineral manures were capable of restoring to a soil, the fertility of which it had been deprived by repeated cropping. On the space of ground which was not manured, the acreage yield was as follows :—

Grain, 16 bushels; straw, 1120 lbs.

This may be considered as the natural produce of the soil, subject only to the atmospheric influence of that particular season. The next experiment was with 700 lbs. of superphosphate of lime, which gave—

Grain, 16¾ bushels; straw, 1116 lbs.

The superphosphate of lime employed in these experiments was made from calcined bone only, and was therefore strictly a mineral manure. By comparing this experiment with the last, it will be seen that practically no increase of produce was obtained.

The effect of superphosphate of lime upon wheat has been the subject of many experiments, and in some instances it has been employed with remarkable success. It becomes therefore of importance to inquire what was the probable cause of its inutility in this instance. Besides phosphoric acid and lime, the ash of wheat and wheat straw contains potash, magnesia, soda, and silica; and as superphosphate of lime contains none of these substances, its failure in this case may be attributed either to the absence of these minerals in the soil, or to a deficiency of azotized or other organic matter.

The average results obtained by other mineral manures are given below :*—

* The terms superphosphate of lime, phosphate of potass, phosphate of

	Bushels of Grain.	Pounds of Straw.
Superphosphate of lime, 350 lbs.; phosphate of magnesia, 420 lbs.	16½	1100
Superphosphate of lime, 350 lbs.; phosphate of soda, 325 lbs.	16¾	1172
Superphosphate of lime, 350 lbs.; phosphate of potass, 375 lbs.	16½	1160
Superphosphate of lime, 560 lbs.; silicate of potass, 220 lbs.	16¼	1112
Superphosphate of lime, 350 lbs.; phosphate of magnesia, 210 lbs.; phosphate of soda, 162½ lbs.	16¾	1116
Superphosphate of lime, 350 lbs.; phosphate of magnesia, 210 lbs.; phosphate of potass, 187½ lbs.	17½	1204
Superphosphate of lime, 350 lbs.; phosphate of magnesia, 210 lbs.; silicate of potass, 275 lbs.	17	1176
Superphosphate of lime, 350 lbs.; phosphate of magnesia, 168 lbs.; phosphate of potass, 150 lbs.; silicate of potass, 110 lbs.	17¾	1240

The greatest increase obtained by these mineral manures over the natural produce of the soil was less than 2 bushels of wheat and 120 lbs. of straw. The effect of minerals obtained from a more natural manuring source (the combustion of dung), gave a similar result. A quantity of farm-yard dung was weighed into two portions, at the rate of 14 tons each per acre, one being burnt to ashes, and the other ploughed into the soil. The results were as under :—

	Bushels of Grain.	Pounds of Straw.
14 tons of farm-yard dung	22	1476
Ash of 14 tons of farm-yard dung . .	16	1104

The absence of any agricultural increase of produce throughout this series of experiments might be said to arise either from some defect in the mineral constitution of the manures, or from the minerals in the soil not being in a proper state for the wheat to assimilate them; but if, as is seen in the following table, the addition of an ammoniacal salt can produce an increase of corn and straw to a considerable extent, the minerals must have been in a state available for the plant :—

soda, and phosphate of magnesia, by which it is convenient to designate the manures, are not to be understood as representing the pure chemical substances bearing those names. The composts were formed by acting upon bone-ash by means of sulphuric acid, in the first instance, in the cases of the alkaline salts and the magnesian salt, neutralizing the compounds thus obtained by means of cheap preparations of the respective bases. The silicate of potass was manufactured at a glass-house by fusing equal parts of pearl-ash and sand—a clear transparent glass, slightly deliquescent in the air, was the result; it was ground to powder under edge-stones.

	Bushels of Grain.	Pounds of Straw.
1. Superphosphate of lime, 630 lbs.; sulphate of ammonia, 65 lbs.	21¼	1368
2. Superphosphate of lime, 350 lbs.; phosphate of magnesia, 84 lbs.; phosphate of soda, 65 lbs.; phosphate of potass, 75 lbs.; silicate of potass, 110 lbs.; sulphate of ammonia, 65 lbs.	21¼	1480
3. Superphosphate of lime, 350 lbs.; phosphate of magnesia, 84 lbs.; phosphate of soda, 65 lbs.; phosphate of potass, 75 lbs.; silicate of potass, 110 lbs.; sulphate of ammonia, 65 lbs.; rape-cake, 154 lbs.	22¾	1768
4. Superphosphate of lime, 350 lbs.; phosphate of magnesia, 106 lbs.; phosphate of soda, 80 lbs.; silicate of potass, 110 lbs.; sulphate of ammonia, 80 lbs.	26¼	1772

On comparing the produce of No. 1 in this table with that of the superphosphate of lime as given elsewhere, it will be seen that the substitution of 65 lbs. of superphosphate of lime by 65 lbs. of sulphate of ammonia has caused an increase of 4½ bushels of corn, and 252 lbs. of straw. Again, the increase shown in No. 4, where 80 lbs. of sulphate of ammonia were employed, is from 8 to 9 bushels of corn, and 532 lbs. of straw, over the produce of the best mineral conditions as given in a former table.

The evidence afforded in these experiments regarding the importance of ammoniacal manures caused us to discontinue the employment of mineral manures alone in the second year. It was highly desirable to ascertain whether the minerals supplied during the first year, and also those naturally contained in the soil, were capable of being taken up by future crops. For this purpose ammoniacal salts alone were subsequently employed on some of the plots :—

Season.	Same Space of Ground each Year.	Grain.*	Straw.
		Bush. Pks. qrs.	Pounds.
1844	Superphosphate of Lime, 560 lbs.; silicate of Potass, 220 lbs.	16 1 3	1112
1845	Sulphate and muriate of ammonia, each 1¼ cwt.	31 3 1	4266
1846	Sulphate of ammonia, 2 cwt.	27 1 2	2244

From the immense increase, both of corn and straw, obtained in the second and third years, without any fresh addition of minerals, it is evident that the deficient produce in the first year could only result from the want of some power in the plant to assimilate those already at its command, and that such a power was not wanting in the succeeding years.

I shall only notice one more set of experiments in connection with this point, and which were tried in the season of 1846 with the wheat manure patented by Professor Liebig, and prepared and sold under his name and authority. On referring to the specification of his patent, it will be seen that his object is to re-

* 1844 total grain, 1845 and 1846 dressed grain only.

duce the solubility of the alkalies by fusing them with lime and phosphate of lime, and to employ those substances which will form a compound resembling the ash of wheat:—

	Dressed Grain.			Straw.
	Bush.	Pks.	qrs	Pounds
1. Unmanured acre	17	3	3	1513
2. 4 cwt. of Liebig's wheat-manure alone	20	1	2	1676
3. 4 cwt. of Liebig's wheat-manure, with 4 cwt. rape-cake	22	3	1	1968
4. 4 cwt. of Liebig's wheat-manure, 1 cwt. each of sulphate and muriate of ammonia	29	0	3	2571
5. 4 cwt. of Liebig's wheat-manure, 4 cwt. rape-cake, 1 cwt. each of sulphate and muriate of ammonia	31	3	0	3007

The superiority which Liebig's manure, when used alone, exhibits as compared with the result of the unmanured space, may be attributed to its containing a small quantity of ammoniacal matter, which was distinctly perceptible to the smell.

The absolute necessity of supplying nitrogen to enable the soil to produce more wheat than it could do in a natural state, is so apparent throughout this series of experiments, that it is difficult to entertain the slightest doubt upon the subject. As long as any available ammonia exists in the soil, so long will mineral manures increase the produce of wheat. If I had commenced my experiments upon a field in high condition, full of animal and vegetable matter, I might have been some years in arriving at the true action of mineral manures: as it was, the first year almost decided the question.

For the last seven years this field has suffered an immense loss of minerals, rendered available to the plant by means of ammonia; and the produce of last year (1846) showed that the mineral condition was still little impaired. The crop now growing shows, however, symptoms of an opposite condition of soil. In some experiments, where no minerals have been supplied, the salts of ammonia are not producing their accustomed effect: an excess of the azotized condition is commencing, and mineral manures will now have to be employed to increase the natural produce of the soil.

The various contradictory results obtained by the application of mineral manures to wheat are completely accounted for when it is known that they only increase the produce in proportion to the available azotized matter existing in the soil. Although I have confined my remarks to the wheat crop, they apply equally to the whole class of plants belonging to the same "natural order." Though they do not thrive equally well in the same climate and soil, I consider them all to be plants in which the nitrogen supplied in the manure is more than what is obtained in the produce. They may for our present purpose be called nitrogen-consuming

plants, in contradistinction to those which are nitrogen-collecting plants, and contain more of this substance than was supplied to them in the manure. Common pasture belongs to the same class of plants as our grain crops: hence we have an additional argument to the number already advanced, in favour of breaking it up in every case where it is not required for ornamental purposes.

The theory advanced by Liebig, that "the crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure," is calculated so seriously to mislead the agriculturist that it is highly important its fallacies should be generally known. The contempt which the practical farmer feels for the science of agricultural chemistry arises from the errors which have been committed by its professors. They have endeavoured to account for, and sometimes to pronounce as erroneous, the knowledge which ages of experience have established; and they have attempted to generalise without the practical data necessary to accomplish their end with success. Agriculture will eventually derive the most important assistance from chemistry, but before it can propose any changes in the established routine of the farmer, it must, by a series of laborious and costly experiments, explain this routine in a satisfactory manner.

Although the experimental results which have been detailed undoubtedly prove that to produce agricultural crops of corn nitrogen must be supplied to the soil in some form or other, two important questions still remain unanswered, namely, first, what amount of ammonia will be required to produce a given amount of corn? or, in other words, what amount of nitrogen must the farmer accumulate in his soil to obtain each bushel of corn beyond the natural produce? Secondly, what are the most economical means at his disposal for securing the necessary supply? The solution of these questions is within the reach of careful experiment and calculation; and, although any data at present at our disposal may be incompetent to a proper treatment of them, it may serve some useful purpose to apply such results as we possess with the view of arriving at some general and approximative knowledge on points bearing so essentially on the economy of agriculture.

It may be considered for our present purpose that a bushel of wheat contains one pound of nitrogen. It must not be supposed, however, that $1\frac{1}{5}$ lb. of ammonia (equivalent to one pound of nitrogen) supplied to the soil, will, even under the most favourable circumstances, add a bushel to its natural produce. Throughout the whole course of my experiments upon the growth of wheat by means of ammoniacal salts there has been a loss of nitrogen far too great to be attributed merely to drainage and

evaporation from the land; and it is possible that a better knowledge than we now possess of the vital actions of plants will, sooner or later, throw much light upon this interesting and highly important phenomenon. I am inclined to think that, for practical purposes, we may assume 5 lbs. of ammonia to be required for the production of every bushel of wheat beyond the natural yield of the soil and season; at any rate, it will be useful to remember this as the amount until further experiments shall furnish further information on the subject. In the following table, p. 24, are arranged some of the results obtained last year (harvest, 1846) in my experimental wheat-field.

Besides the bearing which these results have upon other points than that of the amount of ammonia required to produce a bushel of corn, they will enable any one to judge of the probable exactness of the estimate which has just been made. It should be remembered, however, that as the season of 1846 was more than usually favourable to the production of corn, any calculations founded upon the results of that year might lead to an overestimate of what the ammonia would produce in an average of years. The produce of the unmanured plot and that of farmyard dung was, in dressed grain and straw, as follows—

	Bush.	pks.	qrs.	Straw in lbs.
No manure . .	17	3	3	1513
14 tons of dung .	27	0	3	2454

It was my intention to conclude this paper with some experimental evidence relative to the influence of climate and manures upon the turnip and leguminous crops; but, having extended my observations upon the corn-plants to a greater length than I had at first contemplated, I shall defer the consideration of that subject to a future period. I wish, however, to make a few observations upon the general principles of practical agriculture. Some of them are apparent from the evidence I have already brought forward, but some of them are indicated by the results of other branches of the investigation than those which I have discussed in the foregoing pages.

I have said that soil and atmosphere are the two great natural sources from which plants derive the elements of their growth; the former supplying the inorganic and the latter the organic elements. Besides the minerals of which soils are principally composed, they contain a certain amount of organic matter capable of yielding carbon and ammonia to plants; and the annual amount of ammonia which a soil is competent to yield under the influence of the atmosphere must to a certain extent determine its natural fertility. A Russian soil, said to be one of the most fertile in the world, and which yields fine wheat without manure, gave when analysed by M. Peyen, 24½ lbs. of nitrogen in 1000 lbs. of

Selected Results of Experiments upon the Growth of Wheat by means of Artificial Manures; 3rd Season. Harvest 1846.

Numbers.	Description of Mineral Manures—Acreage Quantities given.	Dressed Corn, in Bushels, Pecks, and quarters per Acre.				Straw per Acre in lbs.			
		The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts Rape Cake, and 2 cwts. Ammoniacal salts.
		bush. p. q.	bush. p. q.	bush. p. q.	bush. p. q.	lbs.	lbs.	lbs.	lbs.
1	2 cwts. Bone-ash	...	22 3 1	29 0 3	...	...	1963	2575	...
2	Do. do. and 2 cwts. Hydrochloric Acid	...	...	*25 3 3	*31 1 3	...	...	*2390	*2936
3	Ash of 3 loads Wheat Straw. . .	19 0 2	23 2 2	*27 0 0	*30 0 3	1541	1721	*2309	*2901
4	4 cwts. Liebig's Manure for Wheat	20 1 2	22 3 1	29 0 3	31 3 0	1676	1968	2571	3007
5	No Mineral Manure (exhausted land)	17 2 2	23 2 3	*27 1 2	*28 3 2	1455	2033	*2244	*2603
6	2 cwts. Bone-ash, 2 cwts. Sulphuric Acid	...	23 1 3	30 0 1	...	...	2133	2715	...
7	Do. do. and 180 lbs. Soda Ash . .	...	24 1 2	28 2 3	...	...	2163	2554	...
8	Do. do. and 200 lbs. Pearl Ash . .	...	24 0 0	29 1 3	...	...	2327	2755	...
9	Do.do. & 84 lbs. Magnesian Limestone	...	23 2 2	26 2 2	...	...	2031	2534	...
10	Do. do. and 60 lbs. Soda Ash, 67 lbs. Pearl Ash, and 84 lbs. Magnesian Limestone . . .	21 1 0	23 3 0	*30 2 0 31 0 0	*30 1 0 33 2 2	1893	2067	*2784 2838	*2836 3278
	Mean results	19 2 2	23 2 1	28 1 3	30 3 1	1641	2045	2546	2901

* Denotes that the ammoniacal salt employed was entirely *sulphate*; in other cases, 1 cwt. *each* of sulphate and muriate were used.

It is to be regretted that, with a view to some interesting points of comparison, the same salt of ammonia was not employed throughout the entire series; the muriate containing a higher per centage of ammonia than the sulphate, its effect might be expected to be somewhat greater, and this indeed is seen to be the case. The series with Liebig's manure (besides the small amount of ammonia it itself contains) may owe its slight superiority over the straw-ash series to the one where no mineral manure was employed, partly to the use of muriate, as well as sulphate of ammonia; on the other hand, the series No. 10 has the advantage over No. 4 throughout.

Selected Results, &c.—*continued.*

No.	Total Weight of Corn per Acre in lbs.				Weight of Dressed Corn per bushel.				Per Centage of Corn to Straw.			
	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.
	lbs.	lbs.	lbs.	lbs.	bush.	bush.	bush.	bush.				
1	...	1549	1988	...	...	63·5	63·6	...	...	78·9	77·2	...
2	...	...	*1777	*2112	...	...	*63·5	*62·5	...	...	*74·3	*71·9
3	1305	1598	*1827	*2076	63·7	63·4	*63·0	*63·3	84·6	92·8	*79·1	*71·6
4	1400	1534	1967	2163	63·7	63·0	63·5	63·4	83·6	77·9	76·5	72·6
5	1216	1614	*1850	*1942	63·8	63·0	*63·6	*63·3	83·6	79·4	*82·4	*74·6
6	...	1628	2055	...	...	63·3	63·2	...	...	76·3	75·7	...
7	...	1661	1955	...	...	63·0	63·4	...	...	76·8	76·5	...
8	...	1660	1998	...	...	63·5	63·2	...	...	71·3	72·5	...
9	...	1605	*1812	...	...	63·0	63·4	...	...	79·0	*71·5	...
10	1474	1592	*2034 2048	*2019 2241	62·0	62·5	*63·0 62·75	*62·7 62·8	77·1	77·0	*73·0 72·2	*71·2 68·3
	1349	1605	1927	2085	63·3	63·1	63·3	63·0	82·2	78·8	75·8	72·1

Selected Results, &c.—*continued.*

No.	Increase in Corn by Manure.				Increase in Straw by Manure.				Increase in Total Produce by Manure.			
	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.	The Mineral Condition only.	Mineral Condition, and 4 cwts. Rape Cake.	Mineral Condition, and 2 cwts. Ammoniacal Salts.	Mineral Condition, 4 cwts. Rape Cake, and 2 cwts. Ammoniacal Salts.
1	...	342	781	...	...	450	1062	...	...	792	1843	...
2	...	...	*570	*905	...	...	*877	*1423	...	...	*1447	*2328
3	98	391	*620	*869	28	208	*796	*1388	126	599	*1416	*2257
4	193	327	760	956	163	405	1058	1494	356	732	1818	2450
5	9	407	*643	*735	-58	520	*731	*1090	-49	927	*1374	*1825
6	...	421	848	...	...	620	1202	...	...	1041	2050	...
7	...	454	748	...	...	650	1041	...	...	1104	1789	...
8	...	453	791	...	...	814	1242	...	...	1267	2033	...
9	...	398	605	...	...	518	1021	...	...	916	1626	...
10	267	385	*827 841	*812 1034	380	554	*1271 1325	*1323 1765	647	939	*2098 2166	*2135 2799
	142	397	720	885	128	527	1033	1388	270	924	1753	2467

The acreage produce as will be seen by inspection, is arranged in four columns, and the manures, the detail of which is given on the left of the figures, were used alone, or with additions, as indicated by the several headings. The effects of the different mineral manures, whether alone or with artificial supply of organic constituents, are thus readily seen by casting the eye *down* each column; and those of different conditions of organic with the same mineral supply are found in a line *across* the four columns.

soil, or nearly 2½ per cent. A very fertile soil sent to me by Sir John Tylden from Somersetshire, and said to yield 40 bushels of wheat annually without manure (a statement afterwards proved to be incorrect), was analysed by Dr. Gilbert in my laboratory, and gave 6·2 lbs. of nitrogen in 1000, or rather more than ½ per cent.; whilst from the soil of my experimental field, which yields about 17 bushels of wheat annually without manure, he obtained in 1000 parts only 2·0 of nitrogen, equal to 1-5th per cent.

Although the amount of nitrogen in a soil, independently of any immediate supply, may determine to a certain extent its powers of producing corn, it is not a sure criterion of the value of different descriptions of soil. The rich clayey soils, in which the largest stores of nitrogen are generally found, are exactly those which derive the least benefit from a rotation of crops. The amount of nitrogen existing in a sandy soil may hardly be appreciable by analysis, but by the free circulation of air through its pores, the accumulation from the resources of the atmosphere through the medium of green crops, and especially of turnips, to a certain extent counterbalances the deficiency. The actual value of a turnip crop must vary very much, according to the texture of the soil. On heavy clays, the decomposition of soil by means of a summer-fallow aided by lime, will often render available more ammonia as well as mineral mixtures, than could be obtained by means of a turnip-crop. Upon light soils, however, nothing can advantageously substitute the collective powers of the turnip. In one soil the accumulation of available stores may be affected by combustion or lime, in the other they must be supplied by a different process. As almost every soil contains mineral matter in an undecomposed state, it must evidently be advantageous to favour its liberation by every possible means; for the more produce a soil can be made to yield without manure, the less manure it will require to bring its produce up to a maximum. It was at one time supposed that by repeatedly hoeing and stirring the soil, it could be made to yield perpetual crops without manure; and although this was carrying the principle too far, it undoubtedly proves the benefit of mechanical operations. Draining, however, offers advantages to the agriculturist superior to any as a means of obtaining the influence of the atmosphere upon the soil. Not only is the surface of the soil exposed to the action of the air, but its influence extends to the depth of the drains themselves. In addition to this advantage, what may be considered as an artificial climate is to some extent obtained. An increased temperature, and the absence of moisture, conditions so essential to the production of grain of fine quality, are the result of draining the soil. Thermometers placed in two soils equally exposed to the sun's rays, one of which is moist and the other dry, indicate very differ-

ent degrees of temperature. The rays of the sun, which only serve to evaporate moisture in the one, will raise the temperature of the other. It follows that plants would grow more rapidly upon a well-drained soil than upon one in an opposite condition, especially during the spring.

It will be remembered how large a quantity of ammonia I found it necessary to supply to my soil each year to restore the substances removed in the previous crop. Besides being expensive, this ammonia cannot be procured in the market in any large quantities; but by cultivating turnips and the leguminous plants, a large amount of this substance is collected by them from the atmosphere. A rotation of crops may in one sense therefore be considered as an economical process for obtaining ammonia; but as the amount obtained by green crops must depend very much upon their bulk, every attention should be paid to their growth. In order to produce the greatest weight of turnips, it is necessary that the soil should be brought to the finest and lightest condition possible by mechanical means, and that it should be manured by a large and available supply of carbon and phosphates. Ammonia artificially supplied is not essential if the soil be not deficient in carbonaceous substances; and where the phosphates are not supplied in sufficient quantity it exerts a most injurious effect upon the plant.

The turnip is essentially a plant which requires artificial aid for its development in agricultural quality and quantity. It is singular that while my soil yields 17 bushels of wheat annually, without manure, the turnips upon an unmanured space were reduced to a few cwt. per acre in three years, and in the fourth only averaged the size of a radish. It is also remarkable that a plant whose office it is to restore fertility to the soil should scarcely be able to exist where wheat was yielding a tolerable crop; but the different effect produced upon two crops by farm-yard dung and superphosphate of lime at once explains this anomaly. Eighty-four tons of farm-yard dung, consisting of decaying straw mixed with the excrement of the farm-horses, applied to one acre of wheat and one of turnips during three years, at the rate of 14 tons per acre per annum, did not, in the acre of wheat, add much more than one-half to the natural produce each year: the turnips, however, were increased to an indefinite extent. Superphosphate of lime, which produced no increase of wheat the first year it was applied, gave in succession three good crops of turnips. The dung which I applied to my wheat increased the produce to an extent equivalent to the amount of ammonia which it may be estimated to contain; but it is evident that the great bulk of 42 tons served little useful purpose, for we find that salts of ammonia have produced each year a larger amount of corn. The whole of the solid matter of the residue, consisting of

organic matter almost destitute of nitrogen, could have been assimilated by the turnip, under the influence of a due supply of phosphates. On poor soils it is quite consistent with scientific principles to employ rich azotized dung for the wheat crop, and to convert the carbonaceous residue into the substance of the turnip by an abundance of phosphates. It would, however, probably be advantageous to have a greater proportion than one-fourth of the farm under turnips each year. At present, upon the Norfolk-system one-fourth of the farm is clover, but broad clover cannot be obtained with certainty so often. If instead of this, one-eighth of a farm was clover and three-eights turnips, a larger proportion of winter food would be obtained, and as much clover grown upon an eighth as has hitherto been grown upon one-fourth of the farm. We have no reason to suppose that one grain crop possesses the power of exhausting the soil more than another. The tenant-farmer should therefore be permitted to grow that crop which is most suited to his soil. On the heavy soils alternate wheat crops might be grown; oats might also be substituted for barley with advantage, whenever the soil has been rendered incapable of complete pulverization, by consuming the turnips upon the land in wet weather.

Having, I trust, shown upon scientific principles that a rotation of crops is indispensible in order to carry out a system of practical and economical agriculture, I shall now endeavour to prove by a few brief observations that to obtain the greatest possible produce from the soil, the production of meat ought to bear a definite relation to the amount of grain exported.

The philosophical considerations to which this subject naturally leads are of the highest interest; but as it would be impossible to treat of them at once clearly and at the same time as briefly as our present object permits, it will be best to turn our attention to some of the more practical bearings of the question.

In feeding stock but a small proportion of the nitrogen in the food is converted into the substance of the animal; the greater portion is restored to the soil as manure. The economy of the production of meat as a means of obtaining manure arises from the greatly increased value of the nitrogen in flesh, as compared with that supplied in the food. Thus 28 lbs. of flesh, worth 14*s*., contains 1 lb. of nitrogen—28 lbs. of peas, beans, or oil-cake, which contain about the same quantity, are not worth more than 2*s*. or 3*s*. To determine the exact proportion of the meat, or rather the live weight of stock which must be produced upon any farm to obtain the greatest possible produce of grain, requires a long and careful series of investigations.

With the exception of one experiment performed by Boussingault, we have no data from which we can calculate the loss of

carbon and nitrogen which a farm sustains by the vital processes of the animals fed upon it, but it is evident that it is most serious. In Boussingault's experiments it appeared that a cow respired in 24 hours as much dry organic matter as was equivalent to 100 lbs. of turnips. This forms a strong argument in favour of the modern system of fattening animals rapidly by means of artificial food. When turnips are plentiful and stock is dear, farmers not unfrequently give their turnips to any person who will bring stock to consume them. And it is a common practice in some places to feed a quantity of half-starved cattle upon straw for the purpose of converting it into dung. It should, however, be understood that the passage of the straw or turnip through the stomach of the animal, far from adding to the quality of these substances as manure, abstracts a large proportion of their valuable elements. There is no magical property in the black mass called dung which did not exist in the straw. Some of the elements may be rendered more rapidly available by the decomposing agency of the animal; but the actual quantity restored to the soil must be considerably reduced. In all cases, therefore, where artificial food is not employed, or when the consumption of food is not attended with profit, it is better to restore the superabundance of green crop more directly to the soil for the after-growth of corn, whilst any residue of our corn crops, if it cannot be used as litter, will, if returned to the soil in its natural state, or after suffering decomposition between layers of earth, supply constituents to the succeeding fallow crop.

The increase of meat obtained by any particular food must vary to a certain extent, with animals of different breeds and ages, as well as with the care and attention bestowed upon them. There is, however, in all cases, a relation sufficiently evident, between the increase of the animal and the nitrogen in the food, to enable us to form some calculation upon the relation which should exist between the production of corn and that of meat upon a well cultivated farm. In illustration of this statement, in the first place I may refer to some experiments made upon the farm of the Earl of Radnor, regarding the feeding qualities of different breeds of sheep. The results are quoted from the last number of this Journal.

In the 1st experiment, 20 sheep received 847 lbs. of hay, 1319 lbs. pulse, and 25,293 lbs. swedes, and the increase of live weight was 400 lbs. In the 2nd experiment 1044 lbs. of hay, and 17,254 lbs. of turnips produced 192 lbs. of increase. Calculating the nitrogen consumed by the first lot, to be in hay 8½ lbs., in the pulse 45 lbs., in the turnips 38 lbs., and taking the per centage of nitrogen in the increase of live weight at 3½, we have in the first experiment—

91½ lbs. of nitrogen supplied in the food.
14 lbs. do. converted into increase.

Upon similar calculations the 2nd experiment gives—

35 lbs. of nitrogen supplied in the food.
7 lbs. do. converted into increase.

In the first experiment 1 lb. of nitrogen produced 4⅓ lbs. increase of flesh, and in the 2nd, 1 lb. of nitrogen produced 5½ lbs. increase; not making any allowance for the probable loss by the vital processes of the animals, and in the preparation of the dung, we have for each pound of nitrogen exported, as much in the first experiment as 6½ lbs.; and in the 2nd, 5 lbs. remaining for manure.

In the 'Gardeners' Chronicle,' for the year 1844, are given the results of some experiments upon feeding sheep conducted upon the farm of the Earl of Ducie, by Mr. Morton; some of these sheep were fed in the field, some under cover. Altogether 25 sheep were experimented upon, and they increased 611 lbs., having consumed 31,580 lbs. of swedes, 2775 lbs. of oats. Calculating the food to have contained 95 lbs. of nitrogen, and the increase of live weight to represent 21 lbs. of nitrogen, 1 lb. of nitrogen produced 6½ lbs. of live weight, and for each pound of nitrogen exported in meat, 3½ remain for manure.

In an experiment of my own, two pigs which consumed food, containing by analysis 12½ lbs. of nitrogen, increased in weight 71 lbs. This gives nearly 5¾ lbs. increased live weight for 1 lb. nitrogen in food, and for every pound of nitrogen exported in increase about 4 lbs. remain for manure.

In Bacon's Essay on the Agriculture of Norfolk, there is a table of the feeding qualities of oil-cake and swedes, compared with a compound of boiled linseed with peas and swedes; six oxen were selected for each trial, and the live weight of each beast was taken at the commencement and the end of the experiments.

The following are the results:—

1.—6 oxen consumed 106,792 lbs. turnips, 3,712 lbs. peas, 1,110 lbs. linseed.
The increase of the live weight being 1,722 lbs.

2.—6 oxen consumed 108,440 lbs. turnips, and 6,183 lbs. oil-cake.
The increase of the live weight being 1,310 lbs.

In the 1st lot the nitrogen in the food was about 335 lbs., 1 lb. of nitrogen gave 5 lbs. of increase in live weight, and for each pound of nitrogen exported 4½ lbs. remained for manure.

In the 2nd lot, the nitrogen in the food was 389 lbs., 1 lb. of nitrogen gave $3\frac{4}{10}$ increase, and for each pound of nitrogen exported 7½ remain for manure.

In consequence of turnips being employed as part of the food, in all the results which I have given, it is impossible to make any calculation respecting the economy arising from fatting cattle as a means of obtaining manure, without first deciding at what expense turnips can be produced. Upon this subject very great difference of opinion exists amongst agriculturists, and indeed the effects of soil and season so materially affect the question, that it is scarcely safe to make any calculations respecting it. Some would value them as low as 7*s*. per ton, some as high as 20*s*.

By the kindness of a friend, however, I have been provided with some results obtained by feeding upon marketable food alone. As the results extend over a considerable number of years, in each of which 30 to 40 oxen were fattened, they may be considered to afford very trustworthy information on the subject.

Each ox received for 22 weeks 20 lbs. of the best clover hay, and 10 lbs. of English oil-cake per day. They sold for 9*l*. more than they cost, and the average loss upon each was 4*l*. 12*s*.

Each ox received 3080 lbs. of hay = nitrogen		49 lbs.
1470 lbs. oil-cake	do.	70 lbs.
	Total nitrogen	119 lbs.

Estimating the increase in live weight according to the increase in money value at 576 lbs., and the nitrogen to amount to 3½ per cent. of their weight, we have 20 lbs. of nitrogen in the increase.

1 lb. of nitrogen gives nearly 5 lbs. of increase live weight, and for each pound of nitrogen exported 5 lbs. remain for manure.

99 lbs. of nitrogen remaining for manure are equivalent to 120 lbs. of ammonia.

To supply the 120 lbs. of ammonia in Peruvian guano of average quality, it would certainly require more than half a ton of that manure, which at the present time would cost 5*l*. The price of ammonia thus obtained would be 10*d*. per lb.

In my experiments upon wheat, it required 5 lbs. of ammonia, to produce a bushel of corn. To obtain this amount of ammonia by means of stock, there should be an increase of about 28 lbs. of live weight upon the farm; or in round numbers, to obtain 1 ton of grain beyond the natural production of the soil, there ought to be an increase in the weight of stock of 1000 lbs. In order to bring an exhausted soil to the highest state of fertility, it will be necessary to produce an amount of meat by means of imported food (such as hay and oil-cake) as will be equivalent to the increase of grain required. As the green crops increase year by year, the same amount of meat will be produced, but the importation of artificial food will gradually decrease to the point at which the internal and external resources of the farm are so balanced as to secure the largest amount of produce from the soil.

I have not tried the comparative feeding qualities of the leaf and the bulb of the turnip; but from the much higher per centage of nitrogen in the former, as determined by analyses in my laboratory, it may be inferred that it is much more nutritive. This would be the case more particularly with the late-sown turnips, when the circulation of the fluids in the leaf is still active, and the plant has not had time to produce a full-sized bulb. It is possible, however, that the relatively low state of elaboration of the constituents of the leaf might interfere with its otherwise apparent applicability as a healthy food.

According to the rule which has been assumed—namely, that the production of 1000 lbs. of live weight increases the yield of grain by 2240 lbs.—the production of 576 lbs. of live weight, as in the cases of the oxen cited above, would give 1290 lbs. increase in grain, equal to 21 bushels of wheat.

This method of fattening bullocks may be considered as the most expensive the farmer can adopt. The whole of the food employed (hay and oil-cake) may be viewed as manufactured articles: it is evident, nevertheless, that artificial manures would have been a dearer source of ammonia than that afforded by the feeding of the animals; but when the other constituents of the several manures are taken into account, the balance will be still more in favour of the fattening process. The dry matter contained in the food of the ox was nearly 4000 lbs; and of this quantity, deducting the little that was converted into the substance of the animal, the only remaining reduction, if the dung be properly manufactured, is in the carbon respired by the animal, which, under the system of agriculture here advocated, is a consideration of no moment. It may appear to some agriculturists that I have entered into details on this subject which are both tedious and unnecessary, but I would solicit a careful consideration of them. I do not at all imagine that the precise relations of ammonia to increase of corn, and of nitrogen in food to nitrogen of live weight obtained, are really such as have been assumed for the purposes of illustrating the views advocated in this paper. My object is to establish as a principle, by which practical agriculture should be guided, that the amount of meat or live weight of stock produced upon a farm, should bear a fixed relation to the quantity of corn exported.

If the truth of this postulate be once established, and the proper proportions fixed, it will no longer be necessary to enforce upon the farmer any particular rotation of crops. So long as a due relation between his production of meat and export of corn were maintained, there would be no fear of an exhaustion of the soil, even if he grew no green crops whatever; and he might safely be left to make his own choice of the means he would adopt.

His object being the production of a certain amount of meat at the lowest possible expense, he would naturally devote his energies to the production of large green crops, in order to limit his outlay in artificial food. Knowing, too, the most profitable conditions upon which his corn could be raised, his chief attention would be paid to the economical supply of food for his stock, in full confidence as to the consequences of his course.

In objection to any rule which may assume a necessary relation between the production of meat and that of corn, it may be maintained that were any cheap and inexhaustible source of ammonia discovered, the production of meat, as the means of exporting corn, should be materially lessened. The difficulties, however, which we may fairly calculate upon as standing in the way of such a consummation, as well as the physiological and commercial considerations which would be involved in its influence, are such that we need not now anticipate the result. Again, the supposition that the artificial manures at present at our command, might, if directly applied to the growth of corn, be adequate to its sufficient production throughout the country, without the aid of green crops in feeding, is satisfactorily met by such calculations as the following:—The county of Norfolk is said to comprise 1,338,880 acres of land: suppose one-half of this to be cultivated on the four-course system, 334,720 acres will be under corn every year. I believe it will not be considered an exaggeration to say that cultivation in this county has increased the natural produce of corn by 10 bushels per acre; and according to my calculations, it would require something like 50 lbs. of ammonia to be supplied in any artificial manure to produce this increase of corn; and considering 1 ton of Peruvian guano to contain 224 lbs. of ammonia, it would require an importation of 74,714 tons to supply the necessary amount for one year. This calculation affords some idea of the value of a rotation of crops.

It is not very difficult to arrive at a correct knowledge of the action and value of artificial manures. They are generally composed of two or three ingredients in a state of concentration, and are far more rapid in their action upon plants than the manure which is produced by animals. They can therefore be applied with greater success to those crops which are required in an artificial condition, and the growth of which cannot be too vigorous.

If there be any truth in my experiments, all hope of obtaining annual crops of corn by means of mineral manures must for ever be abandoned. The employment of potash, soda, magnesia, and silica, has been suggested by chemists, from an imperfect knowledge of practical agriculture. Having found these substances in the ash of the plants, they have concluded that the soil cannot supply them in sufficient quantity. I could bring forward

a great number of experiments, tried at my suggestion upon various soils, which would prove that alkaline manures were quite incompetent to remedy the exhaustion from which they suffered; but the general practice of the best agriculturists is more convincing than a thousand such experiments. Take the case of a soil which has been in the hands of a farmer who has removed from his land successive grain crops, and who has also sold part of his straw and hay, bringing back perhaps a little soot, or some light manure. This system would exhaust the soil of its alkalies to the greatest extent possible. Should it then come into the possession of a man of capital and experience, he may in a few years bring it into high condition without imparting to it a pound of potash or soda, though the course he would probably adopt would indirectly increase the available sources of those substances.

The quantity of alkalies taken up from the soil by a crop of turnips is very great, and yet the artificial manures most commonly applied to grow these turnips contain but little and often no alkalies whatever. As long as bone-dust, superphosphate of lime, or guano, will produce a good crop of turnips, the farmer need be under no apprehension of his soil being destitute of alkalies. The only mineral which, under a proper system of agriculture, it is necessary to restore directly to the soil, is phosphate of lime. Where large breeding flocks are kept, the phosphate of lime exported in the bone of the animal is very great, and many soils are incapable of yielding this in sufficient quantity. Previously to the introduction of guano into this country, large quantities of nitrate of potass and soda were employed as manures. Their value was, by many persons, attributed to the alkalies they contained; but the almost universal substitution of guano shows very clearly that the potash and soda were not the constituents to which their effects were due. At one time I thought it probable that the silicates of potash or soda might prove of some service to grain plants, but repeated experiments with these substances have caused me to alter my opinion.

The strength of the straw in grain crops seems to depend upon a healthy condition of the plant, arising from a properly balanced supply of mineral and organic constituents, as well as upon the influence of certain physical conditions of soil, especially during the early stages of growth. Thick sowing, a cold wet summer, and excess of ammonia, are all injurious to the strength of straw.

Unless straw is sold, there is a constant accumulation of silicate of potash upon farms, arising from the annual decomposition of the soil; and upon some farms the production of straw increases to an injurious extent. It is a common opinion, that artificial manures

act as stimulants, and that the continual employment of them tends to exhaust the soil. This idea is to a certain extent correct; and where they are used injudiciously (as, for instance, when a mineral manure is employed upon corn crops) it would lead to such a result. But if they are employed to increase those crops which are consumed upon the farm, such as turnips and clover, they then become valuable aids to the natural resources of the farmer.

To obtain agricultural crops of clover, tares, and turnips, purely artificial conditions of growth, quite at variance with the natural tendency of the plant, are induced: and it is well known that the crop of clover which will yield the most hay is by no means that which would be selected for seed. These conditions are secured by an artificial supply of certain elements favouring the desired determinations of the plant; and therefore artificial manures may for such purposes be employed with advantage.

If grain crops, as I have endeavoured to show, can be grown at a cheaper rate by the production of meat, than by the direct action of artificial manures, the propriety of adopting the former course to its full extent becomes simply a question of capital. It would require five times as much capital to produce the same amount of corn by means of stock as could be produced by artificial manures. It is the same with the manufacturer who employs a high-pressure or a double-cylinder engine; with the former his capital invested is small, but the interest paid upon it, by the daily consumption of fuel, is very great, while with the latter his invested capital is large, and his daily interest comparatively small. The want of sufficient capital among so large a portion of our agriculturists cannot be sufficiently deplored in a national point of view. They imagine that the greater extent of land they can farm with a limited capital, the greater will be the interest obtained for it; by which means the amount of labour employed is reduced to the smallest possible extent. High prices have hitherto allowed a system of agriculture to be pursued, by which little more than the natural produce is obtained from the soil. But if the average price of corn should ever be reduced to the standard of other countries, a reduction of rent must take place equivalent to this diminution, or the decrease in the value of corn must be balanced by an increased average produce from the soil.

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ON

AGRICULTURAL CHEMISTRY.

TURNIP CULTURE.

By JOHN BENNET LAWES.

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TURNIP CULTURE.

EXPERIENCE is a legitimate and trustworthy guide in all the great practical arts affecting the physical condition of the human race, and, for agriculture, as for many other branches of industry, has attained a considerable degree of progress independently of the aid of science; but in so far as experience, as distinguished from principle, is relied upon, must we be content that the soundest practices should only be adopted by that small proportion of the entire masses who exercise an intelligent observation, and have arrived at rules for future guidance more or less by the lessons of past error. But although the results of investigation into the rationale of well recognised practices should prove them to be in the main consistent with philosophy, rather than show them to be fundamentally erroneous, yet, when it is remembered that a well understood and simply explicable principle is much more easily acted upon and by a much greater number of individuals than are the dictates of the most acute empiricism, the claim of science as an improver, as well as an exponent of the economic arts, must be fully admitted. The young man of average talent and education, by the assistance of principle, attains comparatively early the position which otherwise half a life is spent in seeking. Granting, however, what we are by no means called upon to do, that the best practices of the age are beyond the aid of science, and that their more current adoption rather than their improvement is to be expected, a better knowledge than is now prevalent, regarding the first principles of vegetable growth, will serve to protect the farmer from the many snares into which either fraud or ignorance would lead him. If, then, the results of investigation should tend to explain and to enforce good old practices, rather than to put forth those which are new and untried, the

utility or even the necessity of the application of science to the improvement of our national agriculture will not be the less evident.

The question with the agriculturist is not so much what are the constituents which must exist in his soil for the growth of a given amount of produce? but what constituents or class of constituents does this or that crop exhaust, relatively to another constituent or class of constituents? Looking at the subject in this point of view, we are of opinion that the increased growth of corn may be considered to have a very intimate relationship to the amount of nitrogen supplied to the soil: and since, owing to the scarcity and high price of ammoniacal salts, or other direct nitrogenous supplies, it is impossible to rely upon these sources, a rotation of crops, and the importation of food for stock, come to be not merely the only generally applicable, but the most economical, means of restoring fertility to the soil. Under such a course for the special accumulation of nitrogen, it will be found that there is always secured an abundant coincident supply of mineral and carbonaceous substances, and hence the direct importation of these latter substances is seldom necessary.

The results of our experiments upon wheat and other plants of the gramineous family have indeed shown, beyond a doubt, that the character of the exhaustion which the soil suffers by their growth is essentially and pre-eminently nitrogenous; and since common usage bears ample testimony to the efficiency of alternate cropping, it is to be supposed that an examination into the composition, habits, and sources of growth of the plants which enter into a rotation, would bring to view important functional differences and peculiarities in the different plants, and such as should give confidence in general principles and tend to improvement and economy in practice.

The greatly varying form and appearance of the various agricultural plants, implying, as undoubtedly they do, essential differences in their sources of nutriment, have led, from but superficial observation of them, to erroneous assumptions regarding the true office of certain plants in a course of agricultural cropping. Thus it is by some maintained that the large surface of leaf put forth to the atmosphere by the turnip, taken in connexion with the general character and utility of the crop, bespeaks an almost exclusive reliance upon the natural resources of the atmosphere for its carbonaceous supply; and the direct application of nitrogenous manures has accordingly been recommended with the view of favouring to the greatest extent the development of leaf as a means of securing bulb.

Again, agricultural plants have been arranged according to *their botanical alliances*; and distinctions between the necessary

conditions of artificial supply of certain constituents have been made, which are inconsistent with the dictates of experience, and equally so with those to which we are led when other circumstances besides the (nevertheless important) botanical distinctions are brought into consideration. The varying quantitative reliance upon the atmosphere and the soil of different natural families of plants constitutes indeed a most interesting and important point of study, and the principles upon which the *natural system* is founded may derive essential confirmation from chemical researches; but in referring the varying agricultural value of different plants to the functional characters of the several natural orders to which they belong, it must always be first decided that the natural aim and tendency of the plant and order are favoured by our methods and objects of cultivation, and that the agricultural value of the plant is in no way dependent on a monstrous or artificial development at variance with that of its individual health and reproductive tendencies.

The cultivation, habit, and uses of the turnip are well suited to form a contrast to those of our grain crops; and the plant itself may, to some extent, be taken as the type of the green or fallow crops, a main effect of which is the preparation of the soil for the after-growth of corn. The essentially artificial condition which is induced in the cultivation of the turnip plant, for feeding and manuring purposes, is most strikingly illustrated by the effect of climate and manures upon the quantity and composition of the produce.

We shall now proceed to discuss in detail the results of experiments which have been in progress in the field and in the laboratory for several years, and which were undertaken with the view of elucidating some of the general effects of rotation. From the commencement of the inquiry it has been our wish to avoid, as far as possible, the bias of any of the conflicting opinions which have of late years been put forth upon the important subject under examination, and it will be our endeavour, as we proceed in our Report, impartially to lay before our readers such results of direct experiment as will enable them to form their own estimate of the soundness of any views which we may advocate or adopt.

At the outset, however, it may be well to caution the agriculturist against expecting what we by no means presume to exhibit. The object of the experiments has not been the production of immense crops, but to trace, as far as we were able, the real conditions of growth required by the turnip, and to distinguish these from those of the crops to which it is to a great extent subservient. To attain our object it will be necessary to speak of amounts of produce which may at first sight excite the ridicule

of those who do not fully appreciate the nature of the question at issue; but those who choose to go through the details which we are about to quote will, it is thought, find that a true understanding of them tends much to explain the principles upon which the best agriculture is founded.

Before entering upon a consideration of the turnip results themselves, we shall remind the reader of some of the leading facts which may be assumed, regarding the conditions of growth of the wheat plant.

In the paper on "Agricultural Chemistry" in the last number of this Journal, a series of experiments was quoted for the purpose of showing the effect of *season* and *manuring* upon the growth of wheat; and a careful consideration of them led to some very important conclusions regarding the nature of the exhaustion by corn-cropping, and also as to the varying nutritive and marketable value of specimens of grain having different characters and composition, traceable to known conditions of growth.

It was seen that the varying quantity and the quality of the produce of a plot of land, unmanured during several successive seasons, were materially dependent on the number of rainy days, the inches of rain and the temperature, of the months of May, June, July, and August, during which periods the accumulative and elaborative processes of the wheat plant are most actively determined. The average annual produce of the soil and season, unaided by manure, amounted to about three-fourths of the estimated yield of the neighbourhood under ordinary cultivation—to two-thirds of that of a plot manured by farm-yard dung—and to fully half as much as might be expected from as high a course of farming as the soil and the climate with which we have to deal would justify us in adopting. It is remarkable too that, whilst the quality of this natural produce, as indicated by the relation of corn to straw, and the weight per bushel of the corn, varied year by year according to season, yet the characters of the crops grown by very various and, in some cases, rather high manures, were for each season somewhat similar to those of the produce of the unmanured plot. It is evident, then, that the conditions favourable to an increased growth of wheat are perfectly consistent in *kind* with the natural tendencies of the plant, and that they only differ *quantitatively* from the natural resources of soil and season, and less indeed in this respect than might have been supposed.

The following table exhibits the influence of season upon the produce of turnip-bulb unaided by the supply of manure. The soil upon which the experiments were conducted was a somewhat heavy loam, not well suited for turnips; the previous crops since *manure* having been wheat, clover, wheat:—

Season.	No Manure.				
	Bulb per Acre in				Average weight of bulbs in lbs. and tenths.
	Tons.	cwts.	qrs.	lbs.	
1843	4	3	3	2	0·52
1844	2	4	1	0	0·36
1845	0	13	2	24	0·11

It is seen that in three years the produce of this unmanured plot was reduced from 4¼ tons to 13½ cwts. per acre; in the fourth season (1846) the bulbs only averaged the size of a radish, and were considered to be not worth weighing. This result strikes us as the more remarkable when we reflect that to the turnip is attributed a power of reliance upon the atmosphere for its organic constituents, to which it is supposed is due its efficacy in restoring fertility to the soil, and increasing the after-growth of corn, which itself attains to a moderate crop under the influence of soil and season alone. The evidence here afforded of the totally artificial conditions which are induced in the cultivation of the turnip for feeding and manuring purposes, is of the clearest kind; and we shall have occasion further on to refer to other points than those here given, as illustrating so curious a result.

Our present object is to show the entire absence of any beneficial influence of season upon the growth of the turnip, independently of artificial supply of constituents. An inspection of the two following tables, giving the results obtained by various manures during three seasons, and the characters of the seasons themselves, affords some insight into the general influence of climate upon the growth of the *cultivated* turnip. It must be admitted, however, that the relation is by no means so quantitatively definite as in the case of wheat; whilst the conditions suited to the favourable growth of the two plants are very opposite in kind:—

Season.	Bulb per Acre, in Tons, cwts., qrs., and lbs.												Average weight of Bulbs in lbs. and tenths.		
	12 Tons Farm-yard dung.				Superphosphate of Lime.				Mixed earthy and alkaline Phosphates and Sulphates.				12 Tons Farm-yard dung.	Super-phosphate of Lime.	Mixed earthy and alkaline Phosphates and Sulphates.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.			
1843	9	9	2	9	12	3	2	8	11	17	2	0	1·36	1·47	1·35
1844	10	15	1	0	7	14	3	0	5	13	2	0	1·19	0·81	0·68
1845	17	0	3	6	12	13	3	12	12	12	2	8	1·61	1·17	1·16

A detailed consideration of the produce of the several seasons under different conditions of manuring, as just given, cannot fail to show in which were the climatic influences most favourable to the growth of the cultivated turnip. It will be remembered that, without manure, the produce of the first of the three seasons was much below the most meagre agricultural amount; and that in the third and fourth it dwindled to almost nothing. This table, on the other hand, shows that under a course of manuring the third season yielded the largest crop, and the second invariably the least. The average produce of the first season, where farmyard-dung is employed, is not superior to that of the second season under similar conditions of supply, though it is so in each of the cases where mineral manures alone are used. If we look to the average weight of the bulbs, however, as given in the table, it will be seen that the development was superior in the first year to that in the second, though inferior to that in the third. The seeming depreciation in the first season, indicated by the acreage yield, arose from the adventitious circumstance of the greater destruction of plants by disease in that season, from which cause their number was greatly diminished. The discrepancy is, therefore, apparent rather than real; the result being dependent, not upon the *amount* of supply by season and manure, but upon injury which is more frequently connected with rich than with poor manuring. Again, neither the acreage produce nor the average weight of bulbs, where mineral manures alone were employed, shows so marked a superiority of the third season as compared with the first, as is evinced in the case of the farmyard-dung, by which a large amount of *organic matter* was supplied to the plants. We shall have occasion to show, however, when treating of the effects of *manures* upon the growth of the turnip, that there was a deficiency of *carbonaceous supply in the soil* in the cases where mineral manures alone had been used, which gave to the farmyard-dung its superiority in the third season. Upon the whole it is evident from the results, that of the three seasons the third was by far the best suited to the growth of the turnip for feeding purposes, and that the second was the least so.

Of the real character of these seasons some judgment may be formed by an inspection of the following table, in which is given a summary of the statistics provided by the rain-gauge and the register thermometer, in reference to the climate of the three seasons during the months of July, August, September, and October, which may be considered to include the period of the active growth of the turnip:—

During July (last 14 days).				During August.			
Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.	Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.
1843	59·7	11	1·04	1843	63·4	12	3·38
1844	65 8	3	0·55	1844	59·7	14	1·84
1845	59·4	7	0·97	1845	59·0	17	2·79

During September.				During October.			
Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.	Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.
1843	61·9	5	0·98	1843	49·0	15	2·62
1844	58·9	14	1·38	1844	50·2	17	4·13
1845	54·8	14	1·77	1845	50·0	10	1·39

By such a summary as is here given, of course only the general differences in the seasons are brought to light; but our readers will probably admit that the greatly increased labour of examination, were the table more extended and in detail, would scarcely be compensated for, if the main characters, requisites, and offices of the *turnip season* can be ascertained without it.

A relatively large number of rainy days, an enhanced actual amount of rain, and a low degree of temperature, are prominently the characters which distinguish the assumed turnip season of 1845 from that of the two preceding years, and during a considerable portion of the period, especially, from that of 1843.

Thus, taking the items somewhat in the order in which they are given, we find that in the latter half of the month of July, upon the character of which so materially depended the early development of the plant, and on this its future growth, in the seasons of 1843 and 1845 the temperature was lower than in 1844; and in 1845 the number of rainy days is more than double that in 1844, though somewhat less than in 1843, whilst the total amount of rain was much greater in 1845 than in 1844, and nearly equal to that in 1843. In August we have in 1845 the lowest temperature, the greatest number of rainy days, and, though not the largest actual amount of rain, a quantity large compared with 1844, though below that in 1843. September indicates still the lowest temperature in 1845, a number of rainy days equal to 1844 and far exceeding 1843, and also the largest actual amount of rain. The month of October, on the other

hand, shows in 1845 the *smallest* number of rainy days, as well as actual fall of rain, and a mean temperature not so low as in 1843.

In these facts, even though so general and limited in their indications, there is scarcely one which does not show that the most favourable conditions of growth for our cultivated, bulb-forming turnips are, relatively to those for the seed-producing gramineous plants, a low degree of temperature, a large number of rainy days, and a large actual amount of rain. The seeming deviation from this general postulate, which is indicated by the character of the month of October in the third or best turnip season, is, however, by no means inconsistent with our estimate of the requisites of such a season, but rather conduces still further to account for the observed superiority of effect; for whilst, compared with plants which are cultivated for highly elaborated products, such as the cereal grains, we should expect the mainly accumulative and deficiently elaborative processes of the bulb and leaf forming turnip would require a lower degree of temperature and a greater amount of moisture favouring the circulatory determinations of the plants, there is, nevertheless, a point at which depreciation in temperature is injurious to vegetation. Indeed the full growth of the turnip crop depends greatly on the postponement of the winter temperature, and hence probably arose a real advantage from the relatively high (though actually low) temperature in the October of 1845. Again, the lower the temperature, the less important are a continuity and large amount of rain.

As a general fact it is evident, that the amount of the produce of the turnip is very materially dependent upon the climatic character of the season, not only as in itself a *resource*, but as an *essential agent* in the appropriative power of the plant, however liberal and complete may be the supply of constituents within the soil. Whilst, however, it may frequently happen that the physical characters of the season may be such as not to render available to the plant, and at once profitable to the farmer, the constituents which he has provided by manure, it is evident from the results which have been given, that, *without* an ample manuring, the best adapted season is incapable of yielding an agricultural amount of turnips. It is to be feared, however, that it is more frequently the essential condition of artificial aid, rather than that of natural climatic agency and resource, that is in defect.

Common usage seems to attribute to the turnip, and green crops generally, a power of collection from the atmosphere which is not recognised in our grain-yielding plants; and it may at first *sight* appear inconsistent with this view, that the growth of the

turnip in agricultural quantity should be so essentially dependent on artificial supply as our results would show to be the case. There can be no doubt that there is some truth in this current supposition, but there is little doubt that the power of collection from the atmosphere very materially depends upon the quantity and quality of the supply to the soil by manures; in fact, that upon the judicious and liberal provision of certain constituents by art we must rest our hopes for atmospheric accumulation.

Having shown, then, that climatic agencies constitute an important element in the necessary conditions of growth of our cultivated turnip, and that these are only available when associated with an abundant artificial supply of certain constituents, the question arises—What are the substances which it is essential should thus be provided? This brings us to the second branch of our subject, namely, the influence of *manuring* upon the growth of the turnip.

Having discussed in some detail the comparative characters of the first three seasons during which we have been conducting an extensive series of experiments, under very various yet known conditions of manuring, we are prepared to consider the results of those experiments; and it is believed that those of them which were obtained in the three years referred to will amply suffice to indicate the nature of the necessary supply by manure, and also to lead to some interesting and important explanations regarding the true office of the turnip in a course of agricultural cropping, and the sources of its economic value. We would again remind our readers that the object of the experiments was not the production of large crops, but to learn, by the effects of different and known conditions of supply, in what respect and to what extent the plant was dependent upon the resources which must be kept up by the farmer, and how far he may rely upon the natural yield of the atmosphere; for it is the item of *source* of constituents, as well as that of quantity and quality, which should influence our selection of plants and manures under a truly rational and economic system of agriculture.

The experiments were commenced in the season of 1843, the early part of which, it will be remembered, was greatly superior to that of 1844, and equal to that of 1845 in suitableness to the growth of the turnip; but in the middle and latter periods it was inferior to either of the two succeeding seasons. The soil was a somewhat heavy loam, not well adapted for turnips; but as the plant is cultivated on such land with admitted advantage for rotation purposes, it was well fitted to answer our special ends. The previous crops since manure had been wheat, clover, wheat; so that in an agricultural point of view the soil might be considered

as somewhat exhausted, and therefore in a favourable condition for an inquiry into the influence of supply by manuring. The description of seed was Norfolk Whites. The manures and seed were drilled together on ridges, there being 25 inches between the rows. The plots allotted to each experiment comprised six rows, and consisted of about one-third of an acre. The crop was calculated from weighed quantities taken from measured portions of land, of about one-eighth of an acre for each lot, and extending across the series in three different places.

TABLE showing the results of EXPERIMENTS upon the GROWTH of TURNIPS by MANURES, at ROTHAMSTED FARM, HERTS.

First Season, 1843.

Plot Numbers.	DESCRIPTION OF MANURES. Quantities expressed in weight per acre. Each lot made up at the rate of 14 bushels per acre, with clay and weed-ashes.	Average weight of Bulbs in lbs. and tenths.	Number of plants per acre.	Bulb per acre, compared with No. 2 as 1000.	Bulb per Acre in tons, cwts., qrs., and lbs.				Bulb per Acre, if 4 plants in a square yard = 19,360 in an acre.			
					Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1	12 tons farm-yard dung	1·36	15,571	2962	9	9	2	9	11	15	0	9
2	No manure	0·52	17,940	1000	4	3	3	2	4	9	2	6
3	6½ cwts. rape-cake	1·08	17,043	1967	8	4	3	12	9	6	2	21
4	5½ cwts. rape-cake, 2 bushels yeast	1·16	15,467	1926	8	1	1	11	10	0	2	1
5	8 bushels yeast	1·21	20,240	2622	10	19	2	19	10	9	0	17
6	2½ cwts. superphosphate of lime, 12 lbs. sulphate of ammonia, 4 bushels of yeast	1·33	19,573	2796	11	14	0	22	11	9	3	17
7	56 lbs. sulphate of ammonia	1·03	14,996	1653	6	18	1	25	8	18	0	5
8	2½ cwts. superphosphate of lime, 3½ cwts. rape-cake	1·69	16,096	2894	12	2	1	21	14	12	0	14
9	1½ cwt. superphosphate of lime, 5½ cwts. rape-cake	1·52	15,295	2490	10	8	2	5	13	2	2	17
10	3½ cwts. superphosphate of lime, 1 cwt. rape-cake	1·58	18,019	3042	12	14	3	6	13	13	0	13
11	Refuse matter containing much precipitated phosphate of lime, rape-cake, &c.	1·42	17,928	2734	11	9	0	5	12	5	1	23
12	2½ cwts. superphosphate of lime, 2 cwts. rape cake, 20 lbs. sulphate of ammonia	1·48	17,112	2720	11	7	3	7	12	15	3	9
13	1½ cwt. superphosphate of lime, 1 cwt. rape-cake, 40 lbs. sulphate of ammonia	1·42	16,617	2531	10	12	0	5	12	5	1	23
14	1½ cwt. superphosphate of lime, 5½ cwts. rape-cake, 10 lbs. sulphate of ammonia	1·23	17,790	2340	9	15	3	25	10	12	2	12
15	3½ cwts. superphosphate of lime, 2½ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088	2841	11	17	3	18	15	2	2	0
16	3½ cwts. superphosphate of lime, 1½ cwts. phosphate of magnesia-manure	1·39	19,975	2974	12	9	0	15	12	0	1	2
17	3½ cwts. superphosphate of lime, 150 lbs. phosphate of potass-manure	1·36	19,228	2804	11	14	3	19	11	15	0	9
18	3½ cwts. superphosphate of lime, 84 lbs. phosphate of magnesia, 75 lbs. phosphate of potass	1·35	19,642	2835	11	17	2	0	11	13	1	12
19	As 18, with 30 lbs. sulphate of ammonia	1·49	19,113	3045	12	5	0	13	12	17	2	6
20	3½ cwts. superphosphate of lime, 1½ cwts. rape-cake, 16 lbs. sulphate of ammonia	1·58	16,916	2860	11	19	1	23	13	13	0	13
21	Unburnt bones decomposed by sulphuric acid, 7 bushels	1·48	17,675	2804	11	14	3	19	12	15	3	9
22	4½ cwts. superphosphate of lime	1·47	18,446	2908	12	3	2	8	12	14	0	10
23	Clay and weed-ashes only, 15 bushels	1·32	18,745	2650	11	1	3	21	11	8	0	20

The terms superphosphate of lime, phosphate of potass, phosphate of soda, and phosphate of magnesia, as found in this table, and others which follow it, are not to be understood as representing the pure chemical substances bearing those names. The composts were formed by acting upon calcined bone-dust by means of sulphuric acid in the first instance; and in the case of the alkaline salts, and the magnesian one, neutralising *the compound* thus obtained, by means of cheap preparations of the respective bases.

Were we to look at the results of this Table with a purely agricultural eye, the column of acreage weight of bulb would be sufficient to guide our judgment as to the efficiency of the various manures; but since the object of the experiments is rather to provide a key to the requirements of the turnip than to afford exact examples of manuring, other items than that of the actual acreage results obtained must be taken into consideration in forming an estimate respecting the nature of the conditions which cultivation should be calculated to supply. Manures, indeed, cannot be regarded only as containing certain constituents convertible into the substance of the crops, but also as agents acting beneficially or otherwise according to the form or combinations in which they are supplied, and their adaptation to soil and season. Thus it is known that the casualties and tendencies to disease or prevalence of insects often prove more destructive to the young turnip-plant under high farming, when the soil abounds in animal and vegetable matter, than when it is deficient in such substances; and the number of plants per acre may by such causes be so greatly reduced as to show a better acreage yield under bad than under liberal cultivation. The number of plants per acre must not therefore be overlooked in considering the results of the Table. The average weight of bulb may also be taken as to some extent indicating the relative effects of different conditions of growth. Where we have an increased average weight, as well as a large number of plants, both *agency* and *supply* have been favourable to the requirements of the plant; and although the efficiency of either of them is dependent on that of the other, it may as a general fact be assumed that a high number of plants indicates a favourable *condition*, and a large average weight a favourable *amount* of supply. Bearing in mind these considerations, we have given in the last column of the Table the estimated acreage yield, calculated from the actual average weight of bulb, and supposing a uniform number of plants per acre, namely, 19,360, or 4 in a square yard. Such an arrangement would give about 12½ inches from plant to plant along the rows, and may be taken as affording a more just view of the effects of the manures, independently of the contingencies arising from the manner of their application.

In reference to the results of this first season it must further be remarked, that the previous course having been wheat, clover, wheat, the *peculiar* exhaustion of the soil would be that induced by *corn-cropping;* and if there be any truth in the opinions which we have given elsewhere on this subject, this would imply a deficiency of nitrogen relatively to other constituents, so far as the future growth of wheat would be concerned; and it would appear from the amounts of produce without manure during the three seasons, as already given, that in some important respects the con-

ditions of exhaustion most favourable to an investigation into the effects of *supply* for the growth of the turnip, were not so prominent in the first season as afterwards, when the unaided yield was little more than a weed, so that the entire produce under manures could then be attributed either to their *agency* or their *supply*.

The following selected results, showing the average weight of bulbs and number of plants per acre, yielded by manures which, compared with each other, are respectively mineral, nitrogenous, or carbonaceous, will point to some of the conditions which it is essential to provide for the healthy and rapid growth of the turnip:—

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Number of Plants per Acre.	Average Weight of Bulbs in lbs. and tenths.
2	No manure	17,940	0·52
3	6½ cwts. rape-cake	17,043	1·08
7	56 lbs. sulphate of ammonia	14,996	1·03
16	3½ cwts. superphosph. lime, 1½ cwt. phos. of magn. manure	19,975	1·39
17	,, ,, ,, 150 lbs. phos. potass manure	19,228	1·36
18	,, ,, ,, 84 lbs. phos. mag. 75 lbs. phos. pot. manure	19,642	1·35
22	4½ cwts. ,, ,, ...	18,446	1·47

The figures in the first column show a great destruction of plants under direct ammoniacal supply, as well as considerable depreciation where rape-cake was used; and common experience teaches us that, however useful rape-cake and ammoniacal salts, or guanos containing much ammonia, may be as manures for turnips, substances of their description are never safely applied near to the seed. Other instances than those quoted above from the table at page 12 distinctly show the injurious influence of organic manures when drilled with the seed; indeed, it may be laid down as a general rule that, especially for all spring crops, it is much more safe to apply such matters broadcast, and incorporate them well with the soil. The conflicting accounts which are given of the effects of guano and ammoniacal salts when they are supplied to spring corn crops, and of these manures and rape-cake when used for turnips, are, it is believed, mainly attributable to differences in the manner of their application; and whilst with a very wet season no injury, or perhaps benefit, may arise from the use of the manure drill in such cases, by far the safest course is to sow broadcast.

The second column of the selected results shows for this season of 1843 a considerable superiority in point of *development*, as well as *number*, of surviving plants, under purely mineral by the side of organic manures; and, compared with the unmanured plot,

those having manures only mineral indicate a growth almost threefold in the same space of time, whilst the actual acreage amount of produce is in these cases very nearly as great as in any of the series; indeed, mineral manures alone have nearly trebled the unaided produce of the soil and season.

These results might almost lead us to question the importance of organic manuring for the turnip crop, and to assume that a deficiency in mineral matters was the source of impoverishment in the case of the soil selected for experiment; but as we proceed it will be seen that, however marked may have been the effect of mineral matters in developing the powers of growth of the plant, as long as a sufficiency of organic food remained, yet a point of exhaustion was arrived at when, by a less amount of mineral matter, if in conjunction with organic supply (especially such as could yield *carbon* to the plants), the rapidity of *bulb* formation was materially enhanced.

Before leaving these results it is as well to observe, that notwithstanding the large amount of potass required by the turnip, the direct supply of that alkali did not give a produce superior to that by superphosphate of lime. We shall have occasion to recur to the question, whether part of the effect of the latter manure is not due to its liberation in the soil of alkalis not otherwise available to the plant. All we wish to call attention to at the present is, that there was an abundant amount of alkalis in this corn-exhausted soil, which could be rendered serviceable under suitable management.

The next quotations which we shall make from the table (page 12) will serve to illustrate the effect of the artificial supply of matter for organic formations, aided by certain mineral agency and constituency:—

SELECTED RESULTS.

Plot No.	Description of Manures.	Average weight of Bulbs.	Number of Plants per Acre.
8	2½ cwts. superphosphate of lime, 3½ cwts. rape-cake ..	1·69	16,096
9	1½ ,, ,, 5½ ,, ,, ..	1·52	15,295
10	3½ ,, ,, 1 ,, ,, ..	1·58	18,009
12	2½ cwts. superphosphate of lime, 2 cwts. rape-cake, 20 lbs. sulphate of ammonia	1·48	17,112
13	1½ cwt. superphosphate of lime, 1 cwt. rape-cake, 40 lbs. sulphate of ammonia	1·42	16,617
14	1½ cwt. superphosphate of lime, 3½ cwts. rape-cake, 10 lbs. sulphate of ammonia	1·23	17,790
15	3½ cwts. superphosphate of lime, 2½ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088
9	3½ cwts. superphosphate of lime, 84 lbs. phosphate, magnesia, 75 lbs. phosphate of potass, 30 lbs. sulphate of ammonia	1·49	19,113
20	3½ cwts. superphosphate of lime, 1½ cwt. rape-cake, 16 lbs. sulphate of ammonia	1·58	16,916

It may be objected that the average weight of bulbs, as stated above is in itself small, and that the differences exhibited are too slight to be relied upon as showing a result. We would beg to say, however, that the estimations were taken from the whole of the bulbs that were weighed in each case, amounting to nearly 2000, and that we believe they may be depended upon for our present purpose.

It will be remembered that with mineral manures alone there were, on an average, rather more than 19,000 plants per acre, but a glance at the results just given will show how uniformly the direct supply by the drill of "organic manures" tended to lessen the number. Again, it has been seen that the highest average weight of bulbs (indicating the degree of development) was, by purely mineral manures, 1·47 lb., by sulphate of ammonia 1·03, and by rape-cake alone 1·08 lb. The fact that these conditions of manuring, employed singly, fall far short of their effects when combined, help us to form some judgment as to the point at which the one or another class of constituents seems to fail, either in quantity or in adaptation to the wants of the plant.

Taking the lots 8, 9, and 10, we find the *largest* number of plants where the proportion of mineral supply to that of rape-cake is the greatest, and the *smallest* number where the rape-cake is relatively in excess. The weight of bulbs is *least* where the mineral matters are most in defect, and *greatest* where neither condition was to the other so prominent as in the other two cases.

Again taking Nos. 12, 13, 14, and 15, in which superphosphate of lime was united with both rape-cake and ammoniacal salt, the largest weight of bulb in the entire series of the season is found to be in that case where, with a fair supply of each, no one of the several manures predominated so much as in either of the three other instances just mentioned.

Were we to place unconditional reliance upon mere supply of constituents for *actual conversion into the substance of the plant*, we should expect that the farm-yard dung would give, in every respect, the best crop in the series; but *agency*, as distinguished from mere *supply*, seems to constitute a most important item, affecting the development of those truly artificial conditions of growth which the cultivation of the turnip, for feeding and manuring purposes, so pre-eminently implies. In the farm-yard dung we had undoubtedly the largest provision of nitrogenous, and especially of carbonaceous matter, and it may be supposed that it also brought to the soil such an abundance of all the mineral substances as would be contained in a much larger crop than was produced by it.

The results arranged below will sufficiently prove that, however liberal the supply of all required constituents, the health

and vigour of the plant, or its power of appropriating the food presented to it, depends upon other circumstances than the mere *amount* of that food.

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulb.	Number of Plants per Acre.
1	12 tons farm-yard dung	1·36	15,571
8	2½ cwts. superphosphate of lime, 3¾ cwts. rape-cake	1·69	16,096
15	3¾ cwts. superphosphate of lime, 2¾ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088
18	3½ cwts superphosphate of lime, 84 lbs. phosphate of magnesia, 75 lbs. phosphate of potass	1·35	19,642
22	4½ cwts. superphosphate of lime	1·47	18,446

We see that the farm-yard dung gave a number of surviving plants nearly as small as any in this series, and very far short of that obtained by mere mineral, or frequently by mixed mineral and organic supply. Again, the weight of bulbs is only equal to the lowest resulting from pure mineral manuring, and inferior to that in other cases of such manuring. In Nos. 8 and 15, on the one hand, the *amount* of supply, especially of matter for organic formations, was much less than in No. 1, whilst the average weight of bulb was materially greater. On the other hand, the mineral supply was in these cases less than in 22; but there being in that instance no provision by manure of organic matter, the increased mineral supply was unavailing.

Clay and weed-ashes alone, as in No. 23, are seen to more than double the unaided produce of the soil and season, to give a fair number of plants, and an average weight of bulb nearly three-fourths as great as in any case in the series. This is a curious result, and indicates that certain mechanical as well as chemical conditions of soil, in immediate proximity to the young plant, are essential to a favourable and healthy development of its organs of collection. We learn, too, that in some important respects the resource of food within the soil itself could not have been so low in this first year as it appears afterwards to have been.

There are other points indicated by the results already given, than those to which we have directed attention; but as a consideration of the experiments of the succeeding years will bring them before our readers, we need not enter upon them in this place.

Having examined in detail the results of the first year's experiments, it may be well to reiterate some of the more general and important facts and conclusions which have been elicited. It is clearly shown that, under the influence of the same season, and in a soil which, by corn-cropping, had been brought to that condition of exhaustion which common usage would remedy by the

growth of turnips or other green crops by means of manure, the attempt to grow such *restorative* crop without *supplied* aid,—that is, manure,—is quite unavailing. We see that *agency* as well as *supply* is an essential element to be considered in the choice of manures, and that unless such agency or condition of healthy function be secured, a liberal provision of the *materials* of which the plant is built up may frequently, to a great extent, be useless to it. The matters which are most favourable to the healthy action and rapid accumulation and assimilation by the turnip, are the so called "*mineral manures*," under the influence of which a great regularity of plant and vigorous power of growth are attained. At any rate, in the soil in question, when in a condition of *agricultural exhaustion*, the supply of *potass* by direct manures seems unessential. But the direct supply of phosphoric acid, whether by its reaction upon the soil or a special effect upon the young plant, or from a combination of these influences, seems to enhance the assimilating actions of the turnip to a degree much beyond what could be attributed to it as a *mere constituent*, rather than in some sort an *agent* also. We shall recur further on to this interesting subject.

Of the substances which we may term pure *constituents*, "*organic matters*," and especially such as abound in *carbon*, must be supplied for the production of agricultural crops of turnip-bulbs. These manures, as well as those which are chiefly nitrogenous, should never be concentrated near to the plant in its earliest stages of growth, but only within its reach, when, under the immediate influence of mineral manures, the young plant has so far developed its organs of accumulation, and its healthy vigour, as to be competent to grow faster than the natural atmospheric and soil resources of nitrogen and carbon enable it to do. These are, we conceive, the most prominent indications afforded by the results of this our first season of experimenting upon the cultivation of the turnip. As we proceed in our inquiry we shall see how far they are confirmed by those which succeeded them, and which we shall now endeavour to detail.

The whole produce, leaf and bulb, of 1843, was carted off the land. In the second year the manures had some reference to the condition of soil as effected by the first year's treatment, and the same division of the land, and numbering of the plots, were adopted. The manures were again drilled with the seed, and the mechanical culture of the land before and after sowing, the estimation of the crop, and its entire removal, were conducted as before.

The entire series of results of this second season (1844) are given in the following Table at one view, but we shall make selections *as before, for* the convenience of detailed examination.

TABLE showing the results of EXPERIMENTS on the GROWTH of TURNIPS by MANURES at ROTHAMSTED FARM, HERTS.

Second Season, 1844.

Plot Numbers.	DESCRIPTION OF MANURES. Quantities expressed in weight per acre. Each lot made up at the rate of 14 bushels per acre, with clay and weed-ashes.	Average weight of Bulbs in lbs. and tenths.	Number of plants per acre.	Bulb per acre, compared with No. 2 as 1000.	Bulb per Acre in tons, cwts., qrs., and lbs.				Bulb per Acre, if 4 plants in a square yard = 19,360 in an acre.			
					Tons	cwts.	qrs.	lbs.	Tons	cwts.	qrs.	lbs.
1	12 tons farm-yard dung	1·19	20,096	4875	10	15	1	0	10	15	2	22
2	Unmanured	0·36	13,736	1000	2	4	1	0	3	2	0	25
3	7 cwts. rape-cake	0·27	5,488	294	0	13	0	0	2	6	2	9
4	4 cwts. superphosphate of lime, ½ cwt. phosphate of ammonia	0·92	16,768	3138	6	8	2	0	7	19	0	3
5	4 cwts. superphosphate of lime, ½ cwt. sulphate of ammonia	0·87	14,256	2498	5	10	1	0	7	10	1	15
6	3 cwts. superphosphate of lime, 15 lbs. phosphate of ammonia	0·65	21,632	2867	6	6	2	0	5	12	1	12
7	3 cwts. ground apatite	0·38	17,864	1382	3	1	0	0	3	5	2	20
8	3 cwts. of apatite decomposed by sulphuric acid, containing 200 lbs. apatite	0·71	21,232	3076	6	15	3	0	6	2	2	25
9	As No. 8, with 56 lbs. hydrochloric acid added (sp. gr. 1125)	0·80	20,392	3320	7	6	2	0	6	18	1	4
10	4 cwts. superphosphate of lime, 4 cwts. rape-cake	1·18	13,256	3173	7	0	0	0	10	3	3	24
11	4 cwts. superphosphate of lime, 4 cwts. rape-cake, 15 lbs. phosphate of ammonia	1·29	10,320	2697	5	19	0	0	11	2	3	26
12	5 cwts. superphosphate of lime, land dug 6 inches deep	0·97	20,152	3968	8	15	1	0	8	7	2	19
13	4 cwts. superphosphate of lime, 4 cwts. rape-cake, 2 cwts. common salt	0·30	7,952	482	1	1	1	0	2	11	3	12
14	5 cwts. superphosphate of lime, land trenched with the spade 18 in. deep	0·99	13,360	2683	5	18	1	0	8	11	0	14
15	1 cwt. superphosphate of lime, 4 cwts. phosphate of soda	0·76	19,504	3013	6	13	0	0	6	11	1	13
16	1 cwt. superphosphate of lime, 4 cwts. phosphate of magnesia	0·70	21,336	3024	6	13	2	0	6	1	0	0
17	1 cwt. superphosphate of lime, 4 cwts. phosphate of potass	0·66	20,552	2775	6	2	2	0	5	14	0	9
18	2 cwts. superphosphate of lime, 1 cwt. each of phosphate of potass, soda, and magnesia	0·68	18,624	2572	5	13	2	0	5	17	2	4
19	Same as No. 18, with 15 lbs. phosphate of ammonia	0·73	20,352	3107	6	13	1	0	6	6	0	20
20	2 cwts. superphosphate of lime, 4 cwts. rape-cake, 56 lbs. sulphate of ammonia	0·78	6,832	1084	2	7	3	0	6	14	3	8
21	374 lbs. apatite decomposed by sulphuric acid, containing 104 lbs. sulphuric acid, 270 lbs. apatite	0·85	18,728	3247	7	3	1	0	7	6	3	20
22	5 cwts. superphosphate of lime	0·81	21,205	3503	7	14	3	0	7	0	0	1
23	2 cwts. superphosphate of lime, 56 lbs. sulphate of ammonia, 1½ cwts. nitrate of soda	0·83	10,072	1700	3	15	0	0	7	1	2	20

On reference to the summary as already given of the climatic conditions of the turnip seasons of 1843 and 1844, it will be seen, that in the latter half of the month of July, the low degree of temperature, the number of rainy days, and the actual amount of rain, are all most favourable to the early stages of the plant in 1843. Throughout the months of August, September, and October, on the other hand, the conditions of turnip growth, so far as season is concerned, are more favourable in 1844 than in 1843.

A glance at the mean results of the two years will, however, clearly show that if the climatic influences of the second year were in the main superior to those of the first, some other circumstances must be looked for, as accounting for the great falling off in the development of the plant.

SELECTED AND MEAN RESULTS.

Description of Manures.	Average Weight of Bulbs.		Number of Plants per Acre.	
	1843.	1844.	1843.	1844.
No manure	0·52	0·36	17,940	13,736
Mean of mineral supply	1·39	0·73	19,323	20,377
Rape-cake only	1·08	0·27	17,043	5,488
Mean of mixed mineral and organic supply ..	1·50	0·97	17,230	14,774

It is here seen, that with a more favourable season, excepting during the first few weeks, in 1844 than in 1843, we have nevertheless an inferiority of development under every variety of manuring, and a very marked depreciation in the number of plants, unless where mineral manures alone were used. The destructive effects of organic manures, especially in the absence of rain during the early stages of growth, are here very evident; and the maintenance of healthy action, even under these same climatic circumstances, when purely mineral manures are employed, is clearly shown. We observe, too, that whilst under the influence of this defect of rain during the first period of the season, both the weight of bulbs and number of plants are much less where rape-cake is used alone than even where no manure at all is provided, yet the admixture of mineral manures with the organic, gives the best result in the series so far as development is concerned.

That the cause of the depreciation in average weight of bulbs during this season was, nevertheless, connected with a deficiency of matter for organic formations, and not of mineral supply, the following extracted results will show :—

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulb in lbs. and tenths.
15	1 cwt. superphosphate lime, 4 cwts. phosphate soda, manure ..	0·76
16	1 ,, ,, 4 ,, phosphate magnesia, manure	0·70
17	1 ,, ,, 4 ,, phosphate potass, manure	0·66
18	2 ,, ,, 1 ,, each phosphate potass, soda, and magnesia, manure	0·68
19	As 18, with 15 lbs. phosphate ammonia	0·73
22	5 cwts. superphosphate lime	0·81
5	4 ,, ,, ½ cwt. sulphate ammonia	0·87
10	4 ,, ,, 4 ,, rape-cake	1·18
11	4 ,, ,, 4 ,, ,, 15 lbs. phos. amm.	1·29

Thus, of the purely mineral manures, the superphosphate of lime (No. 22), as in the first year, gives a higher weight of bulb than any of those where alkalies are also supplied. The substitution of 1 cwt. of superphosphate of lime, by half a cwt. of sulphate of ammonia (*see* Nos. 22 and 5), raises the weight of bulb from 0·81 to 0·87; by 4 cwts. of rape-cake (No. 10) to 1·18; and by 4 cwts. of rape-cake, with 15 lbs. of phosphate of ammonia, to 1·29, the highest weight obtained during this season—that by dung not excepted.

The farm-yard dung, as in the previous year, must be supposed to have afforded the most liberal supply of all the matters necessary for conversion into the substance of the plant; yet we find that 4 cwts. of superphosphate of lime, with 4 cwts. of rape-cake, and 15 lbs. of phosphate of ammonia (No. 11), give a higher average weight of bulb than the farm-yard dung; that by the former being 1·29, and by the latter 1·19. We have, however, 20,096 plants per acre by farm-yard dung, and only 10,320 by the artificial organic compost. This deficiency of plants is, however, easily accounted for, by the fact that the dung was ridged in, and the artificial compost *drilled with the seed;* so that the defect of rain during the early stages of the plant, whilst it might only retard growth in the one case, would lead to positive destruction in the other.

The very great destruction of plants, as well as the small weight of bulb, in the case of No. 3, where rape-cake alone was drilled with the seed, further show the impropriety of applying organic manures near to the seed or young plant, and the inefficiency of mere supply of constituents if the healthy development of the collective apparatus of the plant be not secured. The

effects of ammoniacal salts, as they have been before described, depending upon a proper combination with other constituents, are further exhibited in the results of this second year. The variations in the number of plants and weight of bulbs, in Nos. 4, 5, and 6, and also in the results of these numbers as compared with those of Nos. 11 and 20 here given, may be adduced in illustration of this fact.

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulbs in lbs.	Number of Plants per Acre.
4	4 cwts. superphosphate lime, ½ cwt. phosphate ammonia	0·92	16,768
5	4 ,, ,, ½ cwt. sulphate ,,	0·87	14,256
6	3 ,, ,, 15 lbs. phosphate ,,	0·65	21,632
11	4 cwts. superphosphate lime, 15 lbs. phosphate ammonia, 4 cwts. rape-cake	1·29	10,320
20	2 cwts. superphosphate lime, ½ cwt. sulphate ammonia, 4 cwts. rape-cake	0·78	6,832

Thus there is a slight superiority in No. 4 over No. 5, both in development and number of plants; phosphate of ammonia being used in the former, and sulphate in the latter. In No. 6, as compared with the two preceding, the amount of phosphoric acid is diminished, but in a greater degree that of ammonia, to which body may be attributed an injurious effect upon the health of the plant when in excess, or not sufficiently incorporated with the soil, and a beneficial one after not only necessary diffusion has taken place, but the plants themselves have attained some strength and vigour. As might be expected, then, the number of plants is greater, though the average weight of bulbs is less in No. 6 than in 4 and 5.

Comparing with each other Nos. 6 and 11, in which the amount of ammoniacal salts supplied by manure was identical, we find that an increase of superphosphate of lime by 1 cwt., and the addition of 4 cwts. of rape-cake (No. 11), whilst they reduced the number of plants from 14,256 to 10,320 (an effect certainly not due to the superphosphate of lime), at the same time raised the average weight of bulb from 0·65 to 1·29; showing the benefit of the supply of *organic matter* in those cases where it had not proved injurious or destructive to the plants, and the other conditions were such as to favour their healthy growth. Again, in No. 20, as compared with No. 11, the amount of supply by rape-cake is equal; that of ammonia-

salt much greater; but that of the important constituent and agent, superphosphate of lime, is diminished. The result is a very great depreciation, not only in number of plants, but in the average weight of bulbs.

We have now given and examined the results of the first two seasons of our experiments upon the joint effects of *climate* and *manures* on the growth of the turnip bulb; and comparing the general character of the one season and its results with that of the other, we see, that although the climatic or vehicular and accumulative agencies were, during the largest portion of the time of growth, more favourable in 1844 than in 1843, yet the produce was, in the main, much inferior under the superior circumstances of climate. This can only be attributed to deficiency in some essential agency or supply, apart from those of season alone; and since those instances in this season, in which mineral supply is most liberal, show by the number of plants a degree of healthy condition, and yet an inferior rate of growth, we conclude that the soil was exhausted of matter for organic formations. That the defect is carbonaceous rather than nitrogenous, is learnt from a careful comparison of the effects of rape-cake and of ammoniacal salts.

Again, the conclusions elicited by a close examination of this second year's experiments, are seen to be identical in kind with those to which we were led by the first year's results; and in their degree afford even clearer testimony—rather than mere confirmation—on most of the points which had been previously discussed. It is the less important, however, to give a recapitulation in this place, as we have yet the entire results of the third season (1845) to detail; and, having accomplished that part of our task, we shall be prepared to give a *résumé* of the three years' series.

The destructive effects of some substances, when applied near to the seed, led us to sow the manures and the seed separately in the third year of our experiments. The same division into plots was observed as previously; but besides the drilled manures, which, though for the most part mineral, were sown before the seed, and at a somewhat greater depth, the entire series of plots was crossed by bands 72 yards in width; these were sown respectively with rape-cake, ammoniacal salt, and rape-cake and ammoniacal salt together, a sufficient portion being left having drilled manures only. These cross-dressings were sown broadcast, before the ridges first drawn out had been split and turned over, so that there could be little danger of injury to seed and young plants. By this arrangement of manuring, for each of the more than 20 conditions of "ash-constituent" supply, 4 of varying

resource of matter for organic formations were secured; so that the number of experiments was raised to nearly 90.

It is to be regretted that, in the first two seasons of our experiments, the acreage produce of leaf, and the relation of leaf to bulb, were not taken; as climate and manuring have a marked influence on the character of the turnip-crop in this respect, besides that which is known to depend upon the mechanical qualities of soil. A consideration of the relative and actual amount of leaf is, moreover, found to be of material importance in estimating the feeding value, degree of maturity, and probable resources of further growth of the plant. All the statement which we are able to give on this subject in reference to these two years is, that both the acreage weight of leaf, and the proportion of leaf to bulb, were much greater in 1843 than in 1844; there being in the former case a much more liberal provision of organic matter remaining in the soil, though, at the same time, a less amount of rain and a higher temperature. The leaves were weighed in the third year, and so far as the effects of different conditions of manuring, under the influence of one and the same season, are concerned, the results obtained are of some interest.

The results of the third year (1845) are given in five sections or divisions (pp. 26-30), and, for the convenience of reference and examination, the statement of the manures is attached to each of these divisions. The different degrees of maturity exhibited under the influence of the varying supply for organic formations, provided by the cross-dressings, led us to weigh some of the crops at twice, that their progressive changes might be ascertained. The order of maturity which was observed was as follows:—

1st. The lengths under drilled manures only (chiefly mineral).

2nd. Those having rape-cake added.

3rd. Those having ammoniacal salt added.

4th. Those with both rape-cake and ammoniacal salt in addition to the mineral manures.

The first weighing was taken in December, when the leaves under mineral supply had considerably drooped and changed colour; the rest exhibiting degrees of retained vitality in the inverse order indicated above. The second weighing was taken early in January, and three weeks later than the first, as will be seen on inspection of the tables.

72 yards, crossed with Rape-cake.	72 yards, crossed with Rape-cake and Ammoniacal Salt.	72 yards, crossed with Ammoniacal Salt.	110 yards, minerals only.
1			1
2			2
3			3
4			4
5			5
6			6
7			7
8			8
9			9
10			10
11			11
12			12
13			13
14			14
15			15
16			16
17			17
18			18
19			19
20			20
21			21
22			22
23			23
24			24

The plan of the field given above will further show the method of manuring adopted in 1845. In the two previous years each experiment extended from one end of the field to the other; in 1845, bands each of 72 yards down the field, were sown, by hand, across the rows, respectively, with rape-cake equal to 10 cwts. per acre; 10 cwts. rape-cake and 3 cwts. sulphate of ammonia; and 3 cwts. of sulphate of ammonia: the manures given as drilled manures being then drilled down the entire length of the field. Thus, from 3 to 24 inclusive, each plot of land forming one experiment in 1843 and 1844 was, in 1845, divided into 4. The figures represent the same spaces of land each year. For example, No. 2 was unmanured in 1843 and 1844; in 1845 one part was unmanured, one was crossed with rape-cake, one with rape-cake and ammoniacal salt, and one with ammoniacal salt. The plan adopted in 1845 has been continued in 1846 and 1847.

Division 1.—Quantity of Bulb per Acre, in Tons, cwts, qrs., and lbs.

Plot Numbers.	Description of Drilled Manures. Quantities expressed in Weight per Acre.	Drilled Manures only.				Drilled Manures, and 10 cwts. Rape-cake, per Acre.				Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.								Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.							
										First Gathering.				Second Gathering, (3 weeks later.)				First Gathering.				Second Gathering, (3 weeks later.)			
		Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1	12 tons farm-yard dung, ridged in	17	0	3	6					14	18	3	12												
2	Unmanured	0	13	2	24	7	10	0	16	0	9	0	24	1	13	0	0	5	14	1	4	5	0	2	24
3	8 cwts. rape-cake	4	16	0	16	9	8	2	24	4	7	1	20	5	8	2	8	7	3	0	16	8	0	2	8
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	8	17	1	20	12	2	2	8	7	12	0	0	9	7	0	16	7	4	0	0	9	16	2	8
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	5	16	1	18	9	9	2	18	6	7	1	14	8	7	1	20	7	0	3	12	8	6	3	12
6	160 lbs. superphosphate of lime, 5 cwts. train oil	6	10	0	16	9	8	1	4	6	3	2	24	6	16	3	12	6	13	2	24	8	19	2	24
7	12 cwts. sulphate of lime (the refuse of tartaric acid manufacture)	5	13	2	24	10	1	0	0	4	15	1	20	4	8	1	4	7	3	1	20	8	10	2	8
8	400 lbs. calcined bone-dust	10	4	0	16	11	13	3	12	9	12	0	0	10	4	0	0	10	6	0	0	10	12	2	8
9	400 lbs. calcined bone-dust, and hydrochloric acid (equivalent to 268 lbs. sulphuric acid, sp. gr. 1·70)	9	9	1	20	8	13	1	4	8	11	1	20	8	12	2	8	7	1	0	16	7	19	2	24
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	12	18	2	6	13	18	1	4	12	9	2	24	12	14	2	8	12	2	0	0	11	17	1	20
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	13	11	0	0	14	0	1	4	12	9	0	16	12	18	2	8	11	16	0	0	12	17	2	24
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	13	8	2	8	14	5	1	4	12	11	0	16	12	14	0	0	11	4	1	4	13	9	1	20
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	14	10	0	4	13	1	2	8	12	9	1	20	12	6	0	0	9	14	0	0	11	12	1	4
14	11 cwts. superphosphate of lime (land trenched 18 in. deep in 1844)	14	4	0	0	14	9	0	0	13	18	1	4	14	10	0	0	12	8	1	0	13	12	1	4
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	11	15	3	12	12	8	3	12	12	8	2	8	13	0	0	0	11	3	1	20	11	13	2	24
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	12	1	0	0	14	3	2	24	12	14	3	12	12	19	0	16	11	17	2	24	13	4	2	8
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	10	19	0	16	12	19	0	0	12	4	1	14	12	0	0	0	11	13	0	16	11	17	2	24
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. mag. limestone, 157 lbs. pearlash	12	12	2	8	13	18	2	24	12	16	3	22	13	12	0	0	13	1	3	6	13	15	1	20
19	As No. 18, with 1 cwt. sulphate of ammonia	12	7	0	0	11	5	2	8	10	0	3	12	10	16	1	4	9	16	0	0	11	8	2	8
20	As No. 18, with 3 cwts. rape-cake	14	7	2	8	14	6	0	0	12	8	2	10	13	8	0	0	12	9	2	24	12	18	0	0
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	13	2	2	24	14	8	1	20	11	13	1	20	12	6	0	0	12	4	0	0	13	4	2	8
22	11 cwts. superphosphate of lime	12	13	3	12	14	0	2	0	11	0	3	12	11	9	2	24	12	10	3	4	13	5	0	16
23	3 cwts. sulphate of ammonia									3	4	1	4												
24	Mean mixture of all other drilled manures, exclusive of Nos. 1 and 23	13	17	0	0																				
	Mean Results	10	10	0	16	12	3	1	24	9	17	3	12	10	9	2	14	10	0	1	13	11	1	0	16

DIVISION 2.—QUANTITY of LEAF per Acre, in Tons, cwts., qrs., and lbs.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.				Drilled Manures, and 10 cwts. Rape-cake per Acre.				Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.								Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.							
										First Gathering.				Second Gathering (3 weeks later).				First Gathering.				Second Gathering (3 weeks later).			
		Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1	12 tons farm-yard dung, ridged in	7	7	3	2					10	8	3	12												
2	Unmanured	0	14	1	4	4	16	2	24	0	6	2	16	0	18	0	0	4	16	0	0	4	10	0	0
3	3 cwts. rape-cake	4	5	0	0	8	9	1	4	4	14	1	4	4	6	2	8	8	8	1	6	7	18	3	12
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	4	9	1	4	6	6	0	16	6	7	0	16	5	12	0	0	8	2	0	0	6	14	2	8
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	4	8	1	4	6	0	2	24	6	6	3	12	6	0	1	4	8	4	0	0	7	15	0	16
6	160 lbs. superphosphate of lime, 5 cwts. train oil	3	0	3	12	4	9	1	20	5	4	0	0	4	14	6	12	7	5	0	16	5	19	1	20
7	12 cwts. sulphate of lime (refuse of tartaric acid process)	2	19	3	12	4	17	0	0	3	6	3	12	2	8	2	8	5	5	0	16	4	8	2	8
8	400 lbs. calcined bone-dust	3	12	3	12	5	8	1	20	6	12	1	4	5	2	3	12	7	14	3	12	5	17	2	24
9	400 lbs. calcined bone-dust, hydrochloric acid (= 268 lbs. sulphuric acid, sp. gr. 1·70)	4	6	3	12	5	6	0	16	6	18	3	12	5	4	2	8	7	14	3	12	5	6	3	12
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	3	16	3	2	5	14	1	16	5	5	1	20	5	3	1	20	7	5	2	24	7	3	0	16
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	4	14	1	4	5	15	2	24	6	4	0	0	5	3	1	20	7	1	0	16	6	13	1	20
12	11 cwts. superphosphate of lime (land dug 9 in. deep in 1844)	4	9	0	0	5	16	2	8	6	18	1	4	5	9	3	20	8	8	2	8	7	2	3	12
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	6	11	0	10	6	3	0	0	8	4	3	14	7	14	0	0	8	19	1	20	8	9	0	16
14	11 cwts. superphosphate of lime (land trenched 18 in. deep in 1844)	4	4	0	16	6	10	2	24	7	8	2	8	6	7	2	24	8	16	3	12	7	14	1	4
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	3	10	2	14	5	2	0	16	8	0	1	4	5	12	3	12	8	8	2	8	6	12	2	8
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	3	17	1	4	4	15	0	18	6	6	2	8	5	8	3	12	7	3	2	24	6	8	0	0
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 670 lbs. pearlash	3	10	0	0	4	10	3	12	6	0	3	12	5	3	2	24	7	2	2	8	6	6	2	8
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	3	7	2	8	5	12	1	4	6	1	1	20	4	10	3	12	6	16	2	8	5	16	2	8
19	As No. 18, with 1 cwt. sulphate of ammonia	4	8	2	24	6	4	1	20	7	3	0	16	5	18	2	8	8	11	2	24	6	14	0	0
20	As No. 18, with 3 cwts. rape-cake	5	1	0	16	6	5	2	24	7	6	0	0	5	17	0	16	9	5	2	24	6	11	2	24
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	4	5	0	16	6	3	0	0	6	15	1	20	5	0	3	12	6	18	0	0	7	18	3	8
22	11 cwts. superphosphate of lime	4	8	0	0	6	0	0	0	7	0	2	8	5	0	3	12	6	8	2	24	6	13	1	20
23	3 cwts. sulphate of ammonia									1	14	0	8												
24	Mean mixture of all other drilled manures, exclusive of Nos. 1 and 23	3	3	1	2																				
	Mean Results	4	0	0	6	5	14	2	17	6	2	2	0	5	1	3	17	7	11	1	7	6	12	1	13

DIVISION 3.—AVERAGE WEIGHT of BULBS, in Pounds and Tenths.

Plot Numbers.	Description of Drilled Manures. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	12 tons farm-yard dung, ridged in	1·61	. .	1·45	. .	. .	. .
2	Unmanured	0·11	0·67	0·066	0·22	0·50	0·49
3	8 cwts. rape-cake	0·49	0·87	0·47	0·55	0·53	0·80
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	0·92	1·14	0·77	0·89	0·81	0·98
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	0·90	1·04	0·77	0·93	0·72	0·87
6	160 lbs. superphosphate of lime, 5 cwts. train oil	0·59	0·90	0·55	0·62	0·64	0·86
7	12 cwts. sulphate of lime (refuse of tartaric acid manufacture)	0·59	0·94	0·54	0·46	0·68	0·89
8	400 lbs. calcined bone-dust	0·92	1·10	0·94	0·95	0·97	1·00
9	400 lbs. calcined bone-dust, hydrochloric acid (= 268 lbs. sulphuric acid, sp. gr. 1·70)	1·02	1·16	0·99	0·99	0·87	0·96
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	1·18	1·33	1·25	1·20	1·10	1·14
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	1·23	1·38	1·19	1·22	1·11	1·22
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	1·20	1·39	1·19	1·23	1·07	1·25
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	1·38	1·27	1·16	1·20	1·03	1·13
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	1·30	1·33	1·30	1·37	1·19	1·26
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	1·11	1·37	1·14	1·17	1·10	1·16
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	1·11	1·35	1·21	1·25	1·14	1·23
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	1·02	1·27	1·16	1·09	1·13	1·08
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	1·16	1·33	1·18	1·24	1·25	1·29
19	As No. 18, with 1 cwt. sulphate of ammonia	1·16	1·24	1·02	1·09	1·09	1·15
20	As No. 18, with 3 cwts. rape-cake	1·28	1·40	1·18	1·29	1·18	1·23
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	1·22	1·41	1·10	1·15	1·18	1·20
22	11 cwts. superphosphate of lime	1·17	1·33	1·06	1·24	1·17	1·24
23	3 cwts. sulphate of ammonia	. .	. .	0·87	. .	. .	. .
24	Mean mixture of all the other drilled manures, exclusive of Nos. 1 and 23	1·27	. .	. .	. .	. .	. .
	Mean results	1·00	1·20	0·96	1·02	0·98	1·07

Division 4.—Number of Plants per Acre.

Plot Numbers.	Description of Drilled Manures. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
1	12 tons farm-yard dung, ridged in	23,731	. .	23,104	. .	. .	. .
2	No manure	13,296	24,944	15,456	16,848	24,160	23,088
3	8 cwts. rape-cake	21,952	24,240	20,896	22,016	20,544	23,304
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	24,000	23,712	22,368	23,488	20,000	22,496
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	14,544	20,448	19,296	19,776	21,824	21,472
6	160 lbs. superphosphate of lime, 5 cwts. train oil	24,528	23,632	24,992	24,576	23,264	23,424
7	12 cwts. sulphate of lime (the refuse of tartaric acid manufacture)	21,408	23,952	19,584	21,376	23,488	23,616
8	400 lbs. calcined bone-dust	21,896	23,760	22,944	24,132	23,808	23,872
9	400 lbs. calcined bone-dust and hydrochloric acid (=268 lbs. sulphuric acid, sp. gr. 1·7)	20,784	16,672	19,360	19,584	18,272	18,624
10	400 lbs. calcined bone-dust and 134 lbs. sulphuric acid	24,704	23,456	22,368	23,808	24,576	23,360
11	400 lbs. calcined bone-dust and 268 lbs. sulphuric acid	24,624	22,800	23,360	23,712	23,872	23,744
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	25,120	23,072	23,606	23,136	23,520	24,160
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	23,620	23,104	24,128	23,040	21,152	23,008
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	24,464	24,368	23,936	23,872	23,328	24,224
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	23,792	20,384	24,352	24,960	22,720	22,592
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	24,336	23,470	23,584	23,200	23,456	24,032
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	24,160	22,800	23,648	24,608	23,200	24,544
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	24,448	23,404	24,448	24,480	23,392	24,000
19	As No. 18, with 1 cwt. sulphate of ammonia	23,888	20,448	22,112	22,304	20,222	22,304
20	As No. 18, with 3 cwts. rape-cake	25,120	22,896	23,680	23,200	23,680	23,552
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	24,160	22,912	23,712	23,904	23,168	24,608
22	11 cwts. superphosphate of lime	24,352	23,544	23,424	20,800	23,936	23,872
23	3 cwts. sulphate of ammonia	. .	. .	19,328	. .	. .	. .
24	Mean mixture of all the other drilled manures, exclusive of Nos. 1 and 23	24,352	. .	. .	. .	. .	. .
	Mean results	22,962	22,763	22,440	22,705	23,028	23,233

DIVISION 5.—PROPORTION of LEAF to BULB; Bulb as 1000.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
1	12 tons farm-yard dung, ridged in; no drilled manures	433	. .	698	. .	. .	. .
2	No manure	1,041	644	720	545	840	892
3	8 cwts. rape-cake	884	896	1,078	797	1,176	909
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	452	520	837	592	1,126	704
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	758	636	943	718	1,164	930
6	160 lbs. superphosphate of lime, 5 cwts. train oil	467	475	840	693	1,085	664
7	12 cwts. sulphate of lime (refuse of tartaric acid manufacture)	526	482	700	550	737	519
8	400 lbs. calcined bone-dust	356	463	686	504	741	553
9	400 lbs. calcined bone-dust, hydrochloric acid (=268 lbs. sulphuric acid)	458	612	809	606	1,009	669
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	296	410	422	445	602	602
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	348	412	492	438	580	512
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	331	408	550	467	751	530
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	451	470	666	696	925	727
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	296	452	538	440	712	560
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	299	410	644	434	754	561
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	320	335	496	420	604	483
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	319	350	494	432	611	532
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	267	402	472	334	521	423
19	As No. 18, with 1 cwt. sulphate of ammonia	264	551	712	549	876	586
20	As No. 18, with 3 cwts. rape-cake	351	439	557	437	743	510
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	324	426	580	375	509	600
22	11 cwts. superphosphate of lime	345	427	636	436	512	505
	Mean results	416	486	634	521	789	617

With such a mass of experimental evidence before us, it is difficult to select a starting-point such as will lead us to the most natural order of illustration, and the clearest comprehension of the most prominent indications and conclusions. In many respects these results are most interesting, confirming as they do the opinions suggested by those which have preceded them; and affording at the same time data, the consideration of which enables us to determine other important questions than those already attended to.

It will be recollected that the statement given of the character of this third season, compared with that of the second, was, so far as all the conditions shown to be essential to the vigorous growth of the turnip were concerned, very much in favour of the one about to occupy our attention; and it is seen that the acreage produce is pretty uniformly nearly doubled where artificial supply for organic formations is much the same. It is true that the number of plants per acre being much greater than heretofore, some of the actual acreage increase may be attributed to this cause; but all we wish to maintain is the general effect of season upon the growth of the cultivated turnip.

The absolute necessity of a liberal supply of *constituents*, even with the most favourable climatic circumstances, and under the influence of the best observed conditions of self-reliance, or collective power depending on mineral supply, is, however, clearly proved by the results of the farm-yard dung, the unmanured plot, and the mean of the purely mineral manures. They are here given in illustration.

SELECTED RESULTS.

Description of Manures.	Bulb per Acre, in				Average Weight of Bulbs in lbs. and tenths.	Number of Plants per Acre.
	Tons.	cwts.	qrs.	lbs.		
Unmanured	0	13	2	24	0·11	13,296
Mean by purely mineral supply	12	8	2	3	1·16	23,882
Farm-yard dung	17	0	3	6	1·61	23,731

Thus, in the best suited of the three seasons to which our experiments refer, the unmanured plot gives a produce of only 13 cwts. per acre, an average weight of bulb under 2 ounces, and a number of surviving plants little more than half that observed under conditions of artificial supply. In this same season, on the other hand, the farm-yard dung gives the largest acreage produce obtained throughout the entire series of seasons and experiments, a weight of bulb higher than any other manure in the same

season, and a number of plants nearly identical with that under mineral manures only. Again, by mineral supply alone, to which, indeed, as we have seen, may be attributed an influence upon the growth of the plant apart from that which can be traceable to the mere provision of *crop-material*, we have as many tons of produce as the unmanured plot gives cwts., a weight of bulb more than ten times as great, and a number of healthy plants nearly double. By the side of the farm-yard dung, however, which we presume to contain a sufficiency of *all the constituents* of a large crop of turnips, (though, excepting under the influence of continuity of rain and a relatively low temperature, not calculated to develop the most healthy conditions of growth,) we find that the purely mineral manuring, with a number of plants per acre almost identical, shows a formation of bulb within an equal period of time little more than two-thirds as great. We shall presently see that the largest weight of *bulb formed in a given time* is not to be taken as affording an unconditional index to the value or promise of the crop; but in the instances now cited it may, in a pre-eminent degree, be quoted as such; for we know that whilst the plants under minerals only had, when weighed, arrived at their full growth, those having farm-yard dung had still vitality and resources for further development.

Before tracing any further the probable source of the superiority of farm-yard over the purely mineral manure, we will refer to some other of the points which our arrangement of manuring elucidates. In the two former years it was observed that, wherever either ammoniacal salts or rape-cake were drilled with the seed, a great depreciation and irregularity in the number of plants per acre resulted; and it may have appeared to some of our readers that we have, without sufficient ground, referred the deficiency of plants to the manner of applying these organic manures; and that, omitting the indications of the actual acreage results, our reasonings are fallacious. The following summary of the number of plants obtained, when ammoniacal salts and rape-cake are sown broadcast and ploughed in, and of that resulting from the use of mineral manures alone, will show how highly important it is not only to select a manure such as the plant requires, but so to apply it as to ensure a beneficial rather than an injurious result.

The uniformity under the various classes of manures in this season, as compared with others, is very striking; though, as before, the mineral manures give somewhat the higher number. The coincidence throughout the entire series of about 90 different combinations of manures (see Division 4 of Table, p. 29) is such that, for the first time, the acreage amount of produce may be taken as a somewhat true measure of the value of the manures. The drilled

manures, as has already been stated, were this year sown alone before the seed, yet the detailed results given in Division 4 of the Table still afford instances of the injurious effect arising from the proximity to the plant of certain manures, though in so slight a degree as to be almost immaterial.

SUMMARY.*

Description of Manures.	Number of Plants per Acre.
Mean of mineral manures alone	23,882
,, ,, with rape-cake added	22,596
,, ,, with ammoniacal salt added	23,598
,, ,, with both rape-cake and ammoniacal salt ..	22,954

The influence of climatic condition, not only as of itself a source of constituents, but as rendering available the supplies provided by the farmer, is strikingly illustrated by the details next quoted, wherein it is seen that notwithstanding the comparatively large number of plants in 1845, which might be supposed to prevent individual development, there is a marked increase as compared with 1844.

Description of Manures.	Number of Plants per Acre.		Average Weight of Bulbs.	
	1844.	1845.	1844.	1845.
Farm-yard dung	20,096	23,731	1·19	1·61
Mean of purely mineral manures	20,377	23,882	0·73	1·16

It is here seen that, even with so great a number of plants, the average weight of bulb is very considerably higher in 1845 than in 1844. In the case of the dung the supply by manure is not supposed to be better than in 1844. In the case of the mineral manures, however, the quantities were larger than before; but the accumulation of organic constituents must have been almost entirely from atmospheric resources. A comparison of the results of the one year with those of the other, as given above, sufficiently prove then the essential influence of climatic agency for the development of the turnip-bulb in *full agricultural quantity;* but the great defect in formation of bulb within a given time, under the influence of one and the same season, when a full

* It will be remembered that in former years the plants were set out with the view of retaining about four to a square yard, or 19,360 upon an acre; the design in this third year was to increase the number to about five instead of four, which is equal to 24,200 to the acre, and hence the actual numbers in the table just given are much higher than hitherto.

supply of mineral manure only is provided, as compared with that of organic matter, also again teaches how imperative it is that there be a liberal provision of such matter in the soil, if we would produce the largest crop which the characters of the season admit of.

The results already selected from the table do not, however, show us whether this required supply by manure of matter for organic formations should be more prominently *nitrogenous*, as in the case of wheat, or *carbonaceous*. This point we shall presently recur to; but, before doing so, shall study the effects of varying the mineral supply by manure.

The average weight of bulb, as affected by the amount of *free* phosphoric acid, or superphosphate of lime, supplied to the soil by manures, is here given:—

Plot Nos.	Description of Drilled Manures.	Average Weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, and 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
8	400 lbs. calcined bone-dust	0·92	1·10	0·96	0·97
9	400 lbs. calcined bone-dust, and hydrochloric acid = 268 lbs. sulphuric acid	1·02	1·16	0·99	0·87
10	400 lbs. calcined bone-dust, and 134 lbs. sulphuric acid	1·18	1·33	1·25	1·10
11	400 lbs. calcined bone-dust, and 268 lbs. sulphuric acid	1·23	1·38	1·19	1·11
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid	1·22	1·41	1·10	1·18
	Mean of the results by sulphuric acid	1·21	1·37	1·18	1·13

It is seen that, under all the varying conditions of organic supply, the undecomposed bone-dust produced less effect than the decomposed. Hydrochloric acid has caused a slight increase in bulb where there was no organic manure, and where rape-cake or ammoniacal salt only was added; but where ammoniacal salt and rape-cake were employed together, the formation of bulb was less than by undecomposed bone-dust. But a reference to Division 2 of the Table of collected results will show, however, a much larger quantity of leaf under the action of hydrochloric acid, —and, in fact, there was more general growth than by undecomposed bone-dust, though but little tendency to form bulb; yet there is little doubt that eventually, if allowed to mature, the *decomposed* bone-earth would have given much the largest amount of bulb as well as entire plant.

Sulphuric acid, as the decomposing agent, indicates in every case a considerably more rapid determination to bulb than either the undecomposed bone-earth or that acted upon by the hydrochloric acid; and, excepting where ammoniacal salt is superadded, there is a perceptible progression as the amount of acid is increased. Where the ammoniacal salt was used, though the formation of *bulb* is not greater under an increase of acid, there was here, as in the case of the hydrochloric acid, a larger development of *leaf*.

The effect of an equal amount of superphosphate of lime on land ploughed in the ordinary way, or which had been dug 9 or 18 inches deep in the previous year, is here shown:—

Plot Nos.	Land, how Tilled.	Average weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. and 10 cwts. Rape-cake per Acre.
12	Land dug 9 inches in 1844 (11 cwts. superphosphate of lime)	1·20	1·39	1·19	1·07
14	Land dug 18 inches in 1844 (11 cwts. superphosphate of lime)	1·30	1·33	1·30	1·19
22	Land only ploughed (11 cwts. superphosphate of lime) ..	1·17	1·33	1·06	1·17

Excepting in column 2, the rapidity of bulb-formation is slightly the greatest where the land is deeply trenched, and in the exceptional case a larger development of leaf was found. The land dug 9 inches deep also shows a slight superiority over that which was only ploughed. The differences are not quoted as offering any adequate advantage for so expensive a process as spade-digging; but the facts themselves help to indicate the character of the conditions required in turnip culture.

We shall next show the result of the yearly supply of *alkalies*, compared with that from a plot (No. 21) which had been drained of them by a course of ordinary cropping, succeeded by the removal of two crops of turnips:—

In the first two columns, where, as we shall presently show, the *balance* of organic constituents was more favourable to *bulb*-formation than in the other cases, we find a greater development of bulb in an equal period of time by superphosphate of lime alone, than when the alkalies, either separately or united, were supplied with it. It is remarkable, too, that in No. 17, where *potass* was employed, there is a general inferiority observable. Again, of the several alkaline conditions, that where potass, soda, and magnesia are used together is the best. The differences exhibited

Plot Nos.	Description of Alkaline Manures (drilled).	Average Weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, 3 cwts. Sulph. Am. and 10 cwts. Rape-cake per Acre.
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid ..	1·22	1·41	1·10	1·18
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 315 lbs. soda ash	1·11	1·37	1·14	1·10
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 220 lbs. magnesian limestone ..	1·11	1·35	1·21	1·14
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 470 lbs. pearlash .. :	1·02	1·27	1·16	1·13
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, and 157 lbs. pearlash	1·16	1·33	1·18	1·25
	Mean by alkaline supply ..	1·10	1·33	1·17	1·15

are at any rate sufficient to show that there was no advantage derived by the use of alkaline manures in this soil, which had been subjected to an unusually severe exhaustion of them.

We have, indeed, uniformly observed, not only in the case of turnips, but of other plants, that by the direct supply of alkalies no good effect has resulted in the season of the application, though the succeeding crops have apparently, to a small extent, been benefited. It is our opinion that, in the ordinary course of farming, the special supply of alkalies to the soil is exceedingly rarely requisite,—and, if ever it be so, they should never be applied in an *alkaline condition* (which seems to be very prejudicial to healthy vegetation), but always supersaturated by acids. Further, alkalies should not be drilled, but should always be sown broadcast, and well incorporated with the soil. In the case of turnips especially is this to be carefully attended to; and, indeed, it might be almost laid down as a general rule, that those manuring substances which take their value as *mere* constituents of the plant (alkalies and organic manures), should be well distributed through the soil; and those which further exercise an influence upon the health and vigour of the plant, such as superphosphate of lime, should be drilled near the seed.

Whether or not superphosphate of lime owes much of its effect to its chemical actions in the soil, it is certainly true that it causes a much-enhanced development of the *underground* collective apparatus of the plant, especially of *lateral* and *fibrous* root, distributing a complete network to a considerable distance around the

plant, and throwing innumerable mouths to the surface. The extent and direction of the *underground range* of the turnip are at the same time very much dependent on the mechanical condition of the soil; and it is universally known that *tilth* is of the highest importance to the favourable formation of *bulb*. We know that the best relation of bulb to leaf, and, in fact, the best acreage produce of bulbs is in the lighter soils, where there is comparatively little obstruction to the development of fibrous root, and it is in these that the special efficacy of superphosphate of lime has been most observable. We believe that, if the turnip is to be valued for its *bulb-formation*, the aim of our culture must be, not to increase the aboveground organs of collection (the leaves), but the *underground fibrous roots*.

We shall now consider the effects of "*organic manures*" upon the production of turnip bulb; and the facts that will come before us will tend to confirm the views just maintained regarding the essential development of rootlet- rather than leaf-accumulation, as a means of obtaining the turnip in agricultural quantity and quality.

The results collected below will illustrate some of the effects of "organic manures" upon the growth of the turnip:—

Description of Mineral Manures.	Average Weight of Bulbs, in lbs.			
	Mineral Manures only.	Mineral Manures, and 10 cwts. Rape-cake per Acre.	Mineral Manures, and 3 cwts. Sulph. Am. per Acre.	Mineral Manures, 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
Mean of entire series of purely mineral manures	1·16	1·31	1·14	1·10
Mean of four experiments with alkaline supply	1·10	1·33	1·17	1·15
Mean of three experiments with superphosphate of lime	1·21	1·37	1·18	1·13

We may explain that the results in the first column were obtained by means of mineral manures alone, and that, the previous crops having been entirely removed from the land, the organic supplies must have been chiefly derived from the atmosphere. The development of *leaf* was less in these than in any of the other cases. In column 2 there was, besides these same mineral manures, 10 cwts. rape-cake, which may be estimated to provide perhaps 50 lbs. of nitrogen. It was, however, employed in these experiments as supplying a large amount of carbonaceous matter, in which it abounds. In the 3rd column the effects are due to the addition of 3 cwts. of sulphate of ammonia to the mineral manures. In these cases about 60 lbs. of nitrogen is supplied, but no carbon. *In the 4th column* we have the effects of the

addition both of the rape-cake and of the ammoniacal salt to the standard mineral manure; consequently the supply of nitrogen by manure would amount to about 110 lbs. per acre.

It is seen that, whichever mineral condition be taken, the supply of carbonaceous matter has given the largest bulb. Of the two mineral series, the acid and the alkaline, the former exhibits a general superiority in each case, excepting in the 4th column, where the defect is very trifling. In this case, notwithstanding there was a carbonaceous supply equal to that in column 2, the excessive amount of *nitrogenous* matter has prevented a favourable formation of bulb. These mean results clearly show that carbonaceous rather than nitrogenous organic supply is favourable to *bulb-formation*, and the fact is confirmed by the following individual cases:—

SELECTED RESULTS.

Plot Nos.	Description of Drilled Manures.	Average Weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
18	Superphosphate of lime, with potass, soda, and magnesia ..	1·16	1·33	1·18	1·25
19	As No. 18, and 1 cwt. sulphate of ammonia	1·16	1·24	1·02	1·09
20	As No. 18, and 3 cwts. rape-cake	1·28	1·40	1·18	1·18

In all these cases the mineral manure was the same, and, in all, the 2nd column under the cross-dressing of rape-cake shows the best result. Further, looking at each column separately, we find that No. 20 always gives a heavier bulb than No. 19, and, excepting under the cross-dressings of ammoniacal salt, than No. 18 also. The amount of the differences is not indeed great; but when we remember that the results are calculated from nearly 2000 plants in each case, their uniformity and constancy demand that reliance should be placed in them. It is clear, then, that carbonaceous manures aid the development of turnip *bulb*. We shall give one more quotation on this subject:—

	Average Weight of Bulbs, in lbs.			
	No Cross-dressing.	Cross-dressed by 10 cwts. Rape-cake per Acre.	Cross-dressed by 3 cwts. Sulphate Ammonia per Acre.	Cross-dressed by 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
No drilled manure (third season) ..	0·11	0·67	0·07	0·50

The instances before us are of high interest in many points of

view, but we are not prepared to consider them fully until we have detailed the results of an analytical examination of the crops—a subject which we shall presently enter upon. Resuming the question in discussion, we see that whilst ammoniacal salts in no degree restored fertility to this exhausted soil, rape-cake gave a sixfold development. In the 4th column, under an equal amount of rape-cake, we find as usual that the excess of nitrogenous manure has deteriorated the tendency to bulb formation exhibited in column 2.

The contrast observed in the effects of ammoniacal salts upon wheat and upon turnips is very remarkable, and affords a striking illustration of the widely differing requirements and sources of growth of the corn-exporting "white crops," and the home-consumed, meat-producing "green" or "fallow crops," of which classes, respectively, the two plants may be considered as the types.

Hitherto we have only considered the effects of organic manures upon the formation of turnip *bulb*, the amount of which is thought to determine the value of the crop when cultivated for feeding and rotation purposes. It has been seen that a liberal supply of available phosphates and of organic manures abounding in carbonaceous matter are pre-eminently favourable to the desired habit of the plant, and that nitrogenous supply, so essential to the increased growth of corn, is so here only to a very limited extent. Under the influence of ammoniacal manures, however, the production of turnip *leaf* is much enhanced, as the following results will show :—

Description of Manures.	Bulb per Acre, in				Leaf per Acre, in				Proportion of Leaf to 1000 of Bulb.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	
Mean by purely mineral manures	12	8	2	3	4	4	0	14	326
Mean of mineral manures, with 10 cwts. rape-cake added ..	13	4	2	20	5	12	0	21	421
Mean by mineral manures, and 3 cwts. sulphate of ammonia added	11	18	1	24	6	15	0	21	559
Mean by mineral manures, and 3 cwts. sulphate of ammonia (second gathering)	12	5	0	13	5	14	0	17	466
Mean by purely mineral manures, and both rape-cake and ammoniacal salt	11	6	1	11	7	9	0	22	669
Mean by purely mineral manures, and both rape-cake and ammoniacal salt (second gathering)	12	4	3	6	6	15	2	16	554

Thus, comparing lines 1 and 3, we find that whilst, by the addition of ammoniacal salt in the latter case, there is in an equal

space of time half a ton less of bulb, there is an increase in leaf by 2½ tons; and, as shown in the 3rd column, the proportion of leaf to bulb is more than half as much again. Taking lines 2 and 5, the addition of ammoniacal salt, as in 5, gives nearly 2 tons less bulb, but nearly 2 tons more leaf, the proportion of leaf to bulb being again increased by one-half. The gross produce is seen, therefore, to be greater in one of these cases, and as great in the other, under the addition of ammoniacal salts. We have before remarked, however, that whilst at the time of gathering, the crops by mineral manures alone, as in line 1, had probably more than fully arrived at maturity—the leaves having drooped and changed colour—those under rape-cake addition only had but just attained full growth, and those having ammoniacal salts, as in lines 3 and 5, evidently possessed yet unexhausted vitality, especially in No. 5, the case where rape-cake was also supplied. It might be supposed, therefore, that in due course bulbous development would succeed as the increased leaves drooped. The results of the second gathering, taken when the leaves under ammoniacal salt without rape-cake had considerably fallen (those with it being still vigorous), show this to have been the case to a greater or less degree. A comparison of lines 3 and 4 shows an increase of bulb in three weeks of 7 cwts., at the expense of 19 cwts. of fresh weight of leaf. On the other hand, line 6 gives an increase in the same period of 18½ cwts. of bulb, at the expense of only 14 cwts. of fresh leaf. Under ammoniacal salts alone there had therefore been an actual depreciation in fresh weight, indicating at least a loss of vitality, though there was probably no real loss of solid matter. Where there was rape-cake also, however, we find an actual gain in gross weight, and we had undoubtedly a vitality and resource of growth still unexhausted. Comparing line 4 with line 1, the latter has still the largest weight of bulb; and comparing line 6 with line 2, the former is still a ton in advance. Were we to admit, however, that if the crops could have been taken each at the stage of its best yield of *bulb*, there would have been a slight superiority under the nitrogenous manuring, the quantity yielding the effect in these instances could in no form have been economically obtained, even were there no other objection to its use.

The effects of an excess of nitrogen in tending to an unprofitable habit of the plant are further exhibited in page 41:—

It is here seen that whilst farm-yard dung, itself containing some nitrogen, and certainly a very full allowance of carbonaceous matter, gives 17 tons of bulb, we have more than 2 tons less bulb when ammoniacal salt is superadded; but there are at the same time 3 tons more leaf than by dung alone. The 3rd column shows that the actual size of bulb, as well as its acreage produce,

	Bulb per Acre, in				Leaf per Acre, in				Average Weight of Bulbs.	Proportion of Leaf to 1000 of Bulb.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs		
12 tons farm-yard dung	17	0	3	6	7	7	3	2	1·61	433
12 tons farm-yard dung, and 3 cwts. sulphate of ammonia	14	18	3	12	10	8	3	12	1·45	700

was less, under the excessive supply of nitrogen; the 4th, that under the same circumstances the proportion of leaf to bulb was increased by more than one-half. So far as supply of *constituents* is concerned, we could select from the series of experiments several instances where we may reasonably suppose that every constituent, excepting *carbon*, existed more fully in quantity and more favourably in combination than in the dung, yet with its larger *carbonaceous supply to the root* we get the largest crop of bulb in the series. The excess of nitrogenous manure, however, is seen greatly to enhance the leaf-forming tendencies of the plant, which it is true may probably aid carbonic acid accumulation from the atmosphere, but at the same time gives a less profitable appropriation of the resources within the soil; and we shall afterwards see it to be by no means clear that there is with a large production of leaf a proportional *gain* of nitrogen from the atmosphere.

Admitting, then, that the organic manure required for the growth of turnip *bulbs* should be carbonaceous rather than nitrogenous, there is still evidence that, under the influence of a due provision of nitrogen, the vitality or longevity of the plant is greatly increased; and since the turnip crop is required to brave the winter frosts, an early and perfect ripening, such as would be induced by a defect of nitrogen relatively to carbon, whilst it might be coincident with a more *rapid* bulb formation, would by no means be a desideratum. We believe, however, that in the ordinary course of farming, the special supply of nitrogen to the turnip crop, by means of artificial manures, is seldom if ever necessary; for there is no ample source of available carbon which does not provide at the same time a considerable amount of nitrogen. As, therefore, in the case of wheat, we need not study the supply of carbonaceous manures, so, in the case of turnips, it comes to be unnecessary to devote special care to the provision of nitrogen. In the one case the means adopted specially to secure nitrogen to the soil, brings with it enough of carbon; and in the other the peculiarly carbonaceous manures are associated with sufficient nitrogen.

We have argued that for the growth of turnip-*bulb* a soil is

required in such a mechanical condition as shall render it easily permeable to the atmosphere and to the fibrous roots of the plants,—that healthy action and a tendency to development of very extended underground collective apparatus should be induced by the use of the so-called "mineral manures," these never being in an alkaline state, and always containing a considerable quantity of phosphoric acid easily available to the plant,—that after the early stages of the plant are passed, its rapidity of growth depends upon an abundant provision *in the soil* of constituents for organic formations, especially of *carbon*,—that nitrogen must be provided by cultivation, though seldom by special manures,—and lastly, that all these requisites being provided by the farmer, the degree in which his efforts will be availing depends essentially upon certain climatic conditions, comprising a considerable *continuity* and *amount* of rain, as a means of taking up the stores of the soil, keeping up a vigorous circulation in the plant, and supplying the dissolved gases of the atmosphere.

These conditions compared with those which are required in the culture of wheat are opposed to one another in almost every particular, but as we proceed we shall see, that of the observed differences much is doubtless due to the essential distinctions between the tendencies of the natural families to which the plants belong; yet much of it is also attributable to the fact, that in the case of the turnip it is not the seed that is the object of our culture, but a monstrous accumulation which could only take place under a somewhat unnatural or artificial balance of the constituents of supplied food, and under such a condition of climate as should be adverse to seed-forming.

It is known that where the turnip is grown for its natural seed-product, oil, a heavier soil, richer manuring, and, during a considerable period of the growth of the plant, a much higher temperature, are required than when the bulb is to be produced. Under these circumstances there will be much less fibrous root thrown up to the surface,—the root is scarcely bulbous, but fusiform, tapping rather than spreading laterally; the leaves and stem are much larger, both actually and proportionally to the root, and the organic manures should contain more nitrogen and less carbon. Were we then to cultivate the turnip for its most natural products, the treatment it would require would much more nearly approach that adapted for wheat than at present; the deviations from it now observed, and which have been referred too exclusively to the *natural* specialities of the plants, would be greatly lessened, and the character of the plant as a "*fallow crop*" would be lost. It is no objection to this assumption that in selecting plants to transplant for *seed from which to grow bulb*, those having the most symmetrical bulb are chosen rather than

such as are more fusiform, and betray a more abundant seed-forming habit—in this case it is not the most abundant natural seed that is the object of culture, but a seed having a special habit of growth, which habit it is wished to propagate.

There being an evident understood subserviency of the leaf of the turnip to the bulb, and a sort of succession in the order of maturation of these different organs, the latter not being perfected until the former has lost much of its succulence and vigour; this fact, and the special conformation of the plant, as before adverted to, have, in theory, led to an appreciation of forcing a large amount of leaf, which is not consistent either with the full efficiency of the conditions which our researches show to favour *bulb* formation, with the character of the soils best suited to the growth of the turnip-bulb, or that of the plant which is most approved by the practical agriculturist. It is true that relatively to wheat and many other plants, the turnip exhibits a large surface of succulent leaf, which, it is admitted, indicates a greater reliance in one way or other upon the atmosphere; yet all experience, when judging not between the turnip and other plants, but between one turnip and another turnip, values the one in which the proportion of leaf is least and the tendency to bulb the greatest. The description of soil which is called a turnip-soil, again, is just that which is best adapted to formation of fibrous root, and that which always yields a proportionally small amount of leaf. Moreover, the soils which yield the largest amount of leaf are known not only by their general mechanical condition, but by their comparative richness in nitrogen, to be exactly those in which the results of our experiments would lead us to anticipate that the leaf-forming tendency would predominate. In these too, as compared with the lighter ones, an excess of nitrogen in the manure is the more likely to give an undesirable development, for in the latter any increased vigour of growth arising from nitrogenous agency may more easily extend the *underground* organs and determine to bulb-formation than in the former.

We have now given a history of our experiments upon turnip culture during the first three seasons of their course, so far as the conduct of them in the field is concerned, though none, as yet, of the results obtained in the two succeeding seasons, the last of which is now drawing to a close. Details of this kind having, however, already taken up much space, and sufficed, we hope, to elucidate some established rules of practice, we shall defer until a future occasion a further consideration of this branch of our evidence, and enter at once into an account of our researches in the laboratory, as tending not only to confirm or confute con-

clusions otherwise arrived at, but as opening out points of interest, both in science and in practice, not hitherto brought to view.

The atmosphere and the virgin soil being originally the exclusive sources, the former of the "*organic*," and the latter of the "*inorganic*" or "*mineral*" constituents of plants, it has been supposed that the amount of produce which a given space of ground would yield must depend upon its richness in those substances proper to itself, namely, the mineral constituents; and that these being supplied in full quantity, according to the indications of the analyses of the ashes of the crops it is wished to grow, the atmosphere would always prove an ample available resource for the more peculiarly vegetable matters. It will be readily understood that on such a view as this, economy in agriculture would be attained by a very different course of practice from that required were it to be shown that cultivation should effect an artificial accumulation in the soil of those constituents primarily derived from the atmosphere, rather than of such as more especially belong to its own constitution.

The theory referred to has led to the analysis of the ashes of a great many agricultural crops, and upon the data thus obtained (rather than upon a consideration of the requirements actually induced by an artificially enhanced vegetation, or of the real source and destination of the constituents under a course of practical agriculture), recommendations to the agriculturist have been founded, the validity of which it was desirable should be tested by actual experiment, as well as by the presumed dictates of experience. The field results which we have detailed, both upon the subjects of wheat and of turnips, are unfavourable to these opinions and recommendations, and analysis will be found to bear testimony in the same direction.

A knowledge of the composition of our crops, as affected by climate and cultivation, is however of great importance, not only as showing what are the sources which must be relied upon for the various constituents, but as assisting a judgment of the feeding value of the produce, and of the *economy* of the means to the adoption of which the variations in composition may be traced. It is more especially with a view to these points of interest that our results have been sought, and that their bearings will be now considered.

In the course of an analytical examination of an agricultural specimen, the first steps are to determine the percentages respectively of dry vegetable substance and of mineral matters. For this purpose a known weight of the produce is exposed for a length of time to such a temperature as will only expel all the water it contains; a portion is then burnt to an ash, which is *presumed* to retain all the "*mineral*," but none of the "*vegetable*,"

substances of the specimen, the latter having been consumed and vaporized by the burning process. The knowledge which these simple experiments may afford is never to be overlooked in considering the composition of an agricultural product, and estimating its probable value, or the economy of the manuring, or other means which have been employed in its growth. A judgment formed thus alone, however, of the comparative characters of different specimens would be fallacious, owing chiefly to the facts that the dry matter of different specimens of the same kind of plant may differ much in composition, and that a very large proportion of our agricultural produce is not allowed to ripen its seed and attain a somewhat fixed condition of dryness not materially affected by collection, storing, and transmission, but is taken whilst the vital circulation of the plant is still proceeding with considerable vigour, causing, long after removal from the land, a rapid exhalation of watery vapour, tending very much to mislead as to the amount of dry matter really contained in the substance under examination. Unless, then, a series of such specimens—the comparative characters of which are to be estimated—be treated in every respect similarly, as to time of gathering, weighing, &c., serious errors must occur.

When ultimate ripened products are the subjects of examination, there is little difficulty in conducting a series of drying experiments, so that the results shall be true indications of the differences really dependent on climate and culture; and although in such cases the range of variation in the amount of dry matter is small, yet the variations themselves are very significant, bespeaking at once the conditions of growth, and, within certain limits, the probable qualities of the products.

There can be little doubt that, after reliable standards have been fixed, a knowledge of the true undoubted percentage of dry matter in specimens of green produce also might materially aid our judgment of their other characters; but, as yet, neither have we these standards, nor are the methods of different experimenters so uniform that their results can compare one with another. So little, indeed, is really fixed and generally admitted regarding both the methods of and the proper inferences from such experiments, that the results of the same operator will, in his own view, be the more doubted the more he learns of the lesson they are calculated to teach; and before there can be any common argument or comparison conducted on such subjects, there must be some uniformity of method agreed upon. In illustration of this necessity one or two experiments only are needed.

A quantity of turnip-leaves were taken direct from the field to a barn about sunset, and were immediately weighed into lots of 25 and 50 oz. each. These bundles were laid upon straw, and

on re-weighing the following morning were found to have lost more than 6 per cent. If the leaves gathered in the evening had not been weighed for drying until the following morning, an error of 1 per cent. or more in the estimation of dry matter would thus have arisen. We have elsewhere stated that 100 oz. specimens of green wheat-plant lost invariably from 7 to 9 per cent. during the process of separating from each other the leaves, the ear, and the stem, although two persons were employed in the operation.

Again, five turnips, with their leaves, were found to weigh as soon as gathered 16 lbs. 4½ oz.; after exposure two days and nights upon straw, under cover, they weighed 15 lbs. 5½ oz.; and after three days and nights more, 14 lbs. 8½ oz. Thus, if after being gathered 48 hours, 100 oz. had been taken for a drying experiment, it would have been equivalent to 106 oz. of fresh plant; and if after five days, to 112 oz. Five plants were next taken, and the leaves cut off, leaving, perhaps, two inches of stem upon the bulbs. The turnips, thus freed of their leaves, weighed 12 lbs. 8½ oz.; after 48 hours on straw, under cover, 12 lbs. 4½ oz.; and after 3 days more, 11 lbs. 3¾ oz. In this case, 100 oz. taken after being gathered 48 hours would have represented 102 oz. fresh bulb; and after 5 days, 106 oz. These turnip experiments were made in cold October weather; but the amount of loss sustained would of course depend much upon the vigour of growth of the plant, upon the state of the weather at the time, and the temperature of the place where the plants were kept.

It is evident, then, that very serious errors may arise when specimens are received from a distance, or even when they are not, unless special precautions be taken, according to the nature of the produce under examination. Indeed it is exceedingly difficult, when fully aware of these circumstances, so to conduct an extensive series of comparative experiments on green or succulent substances as to obtain results which shall be both actually and relatively to each other open to no objection.

When, in the experiments quoted above, bulbs with the leaves, or the leaves alone are taken, the loss is seen to be much greater than when the bulbs alone are operated upon. This is what might have been anticipated, and shows clearly that the effect is due to the continuance of the natural circulatory processes of the leaves after removal from the land.

In operating upon bulbs or roots which are in contact with the soil, we meet with a difficulty of another kind. In such cases there is always a quantity of soil adhering to the specimens, which, if not removed, will affect to some extent the determination of dry matter, and still more seriously that of the mineral matter. *A single* bulb may be cleaned sufficiently by careful picking and

wiping, but an extended series of determinations cannot be conducted under equal circumstances and with the necessary despatch without washing, by which soluble substances may to some extent be removed, or an absorption of water may take place. With the view of ascertaining the degree of error to which the washing of bulbs for drying and burning may lead, six lots, consisting each of five turnips, were taken, and the leaves were cut off, leaving a sufficient handle; three of the lots were carefully cleaned without the use of water, the other three being scrubbed with a brush in water, in which they were allowed to remain for ten minutes or a quarter of an hour; they were then taken out, rubbed dry with a cloth, sliced, and weighed. After exposure to a temperature of 212° for a sufficient time, the percentages of dry matter were as under:—

Lot.	Without washing.	With washing.
1	8·36	7·96
2	8·03	7·79
3	7·64	7·30
Average	8·01	7·68

There was evidently some difference in the specimens themselves, but the washing process gives in the main a less percentage of dry matter than the other. Without washing there must always be expected a small excess, and with it a slight deficiency. In the particular instances quoted the deficiency was likely to be greater than in the usual conduct of the process, as the operation was purposely rather prolonged, that the extreme effects might be ascertained. It is admitted, however, that washing is an objectionable procedure; but when drying and burning experiments are conducted on an extended scale, the results will be more uniform in character and more comparable one with another than were any other method adopted, as all such either take up so much time that the specimens must, with the risk of change of weather, be collected at different times, or so many persons must be employed that the desirable surveillance is impracticable.

Having given thus far some general statement as to the manner in which our drying results have been obtained, those of our readers who understand such matters will be able to decide for what purposes our figures may be relied upon, and wherein they are likely to be wide of the exact truth. For ourselves, we are of opinion that, taken in series rather than individually, they may be trusted in discussing any points with which our general knowledge

of such subjects will lead us to deal, and that they very closely represent the exact facts.

The following dry-matter results (p. 49) refer only to the produce of the third year's experiments (season 1845). The entire series is tabulated.

Were we to consider each of these results *seriatim*, with a view to trace the variations in the produce to variations in the composition of the mineral or of the organic manures, we should find numerous exceptions to any generalization to which we might thus be led. When we look, however, at extreme instances, or at series strictly comparable one with another, we cannot fail to see some undoubted general connexion between the amount of dry matter on the one hand, and such character or stage of growth as we have already observed to result from certain conditions of manuring on the other. We must be careful, however, to bear in mind the nature of the substances on which we have been operating, and the various circumstances which have been pointed out as tending to vitiate the legitimacy of any comparisons; otherwise we may place undue reliance on single results, or, finding these discrepant with others, come to the conclusion that we have no lesson taught us by so extensive and laborious a course of experiments. With our present limited knowledge, it is, moreover, desirable to exercise great caution in applying to practice the indications of results of this kind.

It must be remembered, then, that the turnip plant cultivated as food for stock is gathered at no well-defined stage of its growth, but whilst containing a vast amount of circulating fluid, the proportion and concentration of which is subject to constant variation under the influence of the still active vital processes of the plant, the varying stores of moisture and of food presented to the roots, and the circumstances of temperature, light, and moisture of the atmosphere, to which the leaves are exposed. In fact, we might liken the growing turnip to an animal whose gross composition would vary according to his resources of food and drink, and the condition of exhaustion or waste to which he is exposed. At one time his stomach and blood-vessels are full, and at another their contents bear a much lessened relation to the more fixed portion of the body.

The water existing in the Norfolk-white turnip-bulb is seen to constitute more than nine-tenths of its entire weight; and if it should appear that the proportion varies according to the stage of growth, it will be admitted that the degree of maturity of a succulent plant which is to be the subject of a drying experiment, must be regarded, in deciding its probable yield of solid food, as resulting from various manures; for if the amount of water is *found* to decrease accordingly as the plant matures, that one which

TABLE showing the Percentage of DRY MATTER in Specimens of Turnip Bulb, grown by various Manures. Season 1845.

Plot Numbers.	DESCRIPTION OF DRILLED MANURE.	Drilled Manures only.	Drilled Manures, and Top Dressing of Rape-cake.	Drilled Manures, and Top Dressing of Ammoniacal Salt.	Drilled Manures, and Top Dressing of Rape-cake and Ammoniacal Salt.
1	12 tons farm-yard dung, ridged in	7·83	7·92	7·30	8·86
2	Unmanured	..	8·68	8·71	8·29
3	8 cwts. rape-cake	7·80	7·38	7·77	7·92
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid	8·20	7·66	7·71	7·55
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	8·77	7·95	7·64	7·73
6	160 lbs. superphosphate of lime, 5 cwts. train oil	8·41	8·26	7·92	7·50
7	12 cwts. sulphate of lime	8·56	8·00	8·05	8·00
8	400 lbs. calcined bone-dust	8·71	8·57	7·77	7·83
9	400 lbs. calcined bone-dust, hydrochloric acid equivalent to 268 lbs. of sulphuric acid (sp. gr. 1·70)	8·24	8·87	7·50	8·42
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	8·11	8·65	7·46	7·70
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	8·03	7·67	7·41	7·59
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	8·71	8·19	7·29	7·61
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	7·77	7·41	6·65	6·77
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	9·30	7·26	6·92	7·08
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	8·23	7·14	7·41	7·33
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	8·69	7·61	8·20	7·22
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	8·27	8·49	7·27	7·79
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	7·95	8·36	7·42	7·77
19	As No. 18, with 1 cwt. sulphate of ammonia	7·83	7·69	7·45	6·89
20	As No. 18, with 3 cwts. rape-cake	6·98	7·64	7·95	6·86
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	8·13	7·58	7·64	6·77
22	11 cwts. superphosphate of lime	8·24	7·83	7·36	7·38
	Mean results	8·22	7·95	7·60	7·58

after an equal period of growth is found to contain most water would, conditionally, indicate a more extended further growth, and the manure under which it had grown might be better rather than worse than that to which the more solid turnip owed its character. Again; a series of plots under different manures, though they will be characterized by an undoubted difference in the stage of maturity of the plant, will each within itself exhibit a wide range of variation in this respect, and it is impracticable to gather specimens which shall certainly and exactly represent the characters induced by the manuring of the plots. In our experiments, from ten to twenty plants of average size, and which appear to be sound and firm, are selected from each plot, and from these, when washed and sliced, a weighed quantity is taken; in some cases 100 oz., and in some 150 oz.; in some more, and in some less. The results given in the table were obtained from specimen lots of 150 oz. each, and the soil, season, variety of turnip, and time of sowing and gathering, were the same throughout.*

From these remarks, our readers will be able to judge for themselves whether too much or too little is based upon our results. We feel, however, that it will be much more conducive to the interests of agriculture that the error should be in the latter rather than in the former direction.

The following mean results exhibit the general bearings of the experiments more clearly and safely than individual selections would do:—

Description of Drilled Manures.	Dry Matter, per cent.			
	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
Mean of 13 purely mineral manures ..	8·34	7·97	7·41	7·48
Mean of 4 experiments with alkaline phosphates	8·28	7·90	7·57	7·53
Mean of 3 experiments with superphosphate of lime	8·09	7·97	7·50	7·35

These means show a striking uniformity in the amount of dry matter in each column taken separately,—that is, under the influence of various mineral manures, but a like resource for organic formations. Comparing column with column, however, we find a difference which, though not actually great, must be admitted to have some meaning, when we bear in mind the uniformity within the columns themselves. Were we to compare these

* The conditions of manuring alone were different, and we may therefore rely upon the general indications of the experiments, so far as the effects of manures *are concerned.*

effects of organic supply upon the percentage of dry matter with those of the same conditions upon the average acreage produce, no correspondence, either direct or inverse, would be clearly defined; for we see in the table just given a pretty uniform depreciation from the first column to the third, and the fourth is not wide of the third, but the acreage amounts of produce were as under:—

AVERAGE Acreage Produce of Bulb, in tons, cwts., qrs., and lbs.

Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.
12 8 2 3	13 4 2 20	11, 18 1 24	11 6 1 11

We have before stated, that at the time of the first gathering of the crops, a short time prior to which the specimens for analysis were taken, the plants growing by purely mineral manures were very markedly the *ripest*, their leaves having much drooped; next in order, in this respect, came those having rape-cake in addition; then those having sulphate of ammonia; and, lastly, those with both rape-cake and ammoniacal salt. The proportion of leaf to bulb at the time of weighing shows this to some extent. It was as under:—

	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
Proportion of leaf to 1000 of bulb ..	326	421	559	669
Mean percentage of dry matter ..	8·34	7·97	7·41	7·48

We have, then, the largest amount of dry matter with the ripest bulb and poorest supply of organic manure, very nearly the smallest amount of dry matter with the plants least advanced to the point of heaviest bulb, but which had the largest stores of food in the soil, and probably the prospect of the longest life and fullest eventual growth, at least of entire plant, if not of bulb itself. The second weighing of the crops did indeed show in this case an increase in bulb and a decline in the proportion of leaf to bulb. Here, then, the influence of manures is indirect; for the proportion of dry matter is seen to be mainly dependent upon the degree of maturity of the plant,—and that this is affected by manures has been already shown; and since the largest proportion *of dry matter may* show an early advanced stage

of maturity, frequently arising from an exhaustion of the materials of growth, it may in fact bespeak the worst manuring condition, all other circumstances being equal. It is evident then, that, even supposing the percentage of dry matter to be an unconditional measure of the feeding value of any particular specimens, no comparison could be drawn respecting the efficiency of the manures by which they were grown, unless every other condition, whether of season, soil, maturity, or variety, were considered in their influence; and then, indeed, the effects of the manures may be due to a forcing rather than to a supporting power. We shall have further proof, however, that the amount of water existing in the turnip depends upon the proportion of circulatory to the more fixed matter, and that as the plant matures that of the former diminishes and that of the latter increases; and it will also be seen that equal weights of dry matter may differ very greatly in probable nutritive value.

Before leaving the results of the table, we may observe that by this series of nearly 100 different manures, the utmost variation in the proportion of dry matter in the Norfolk-white turnip-bulb is, after an equal period of time, 2·65, or about 2½ per cent., notwithstanding that there was a vast difference in the stage of maturity of the plants; and it is thought that if the specimens could have been taken each at the point of its fullest growth, the variation strictly dependent on manures would have been much less. The highest percentage of dry matter in the entire series is 9·3,—all the rest are below 9, more than half below 8, and several below 7; the limit of difference, even under the actual circumstances, is, however, in by far the larger number of cases within 1 per cent. Boussingault gives 7·58 per cent., which agrees pretty well with our determinations, the mean of which is 7·83; other observers having found a range in the proportion of dry matter of the turnip-bulb from this amount to nearly double, have attributed much of the variation to the conditions of manuring; but the foregoing facts, in conjunction with those we shall now state, will show that no judgment of the effects of manures in this respect can be formed unless the experiments are made with the same variety of the plant.

The specimens here referred to were grown in different fields, and by different manures, and several of them in the ordinary course of the farm. The 90 lots of experimental Norfolk-whites give a number for the mean percentage of dry matter identical with that found under farm-yard dung, and their extreme variation is 2·65. The two specimens of green common turnips show the same amount of dry matter with a difference of manuring. The various swedes again differ considerably from one another, *yet in a* greater degree from the common turnips. The extreme *variation in the entire* series quoted is from 6·65 in the Norfolk-

Description of Turnips.	Percentage of Dry Matter in Turnip Bulbs.
Norfolk White (lowest of experimental series)	6·65
„ „ (highest of experimental series)	9·30
„ „ (mean of experimental series)	7·83
„ „ by farm-yard dung in experimental series	7·83
Green common turnip, by farm-yard dung	7·94
„ „ by superphosphate of lime	7·94
Swede, Skirving's green top	9·04
„ „ purple top	9·61
„ purple top (old variety, name unknown)	12·25

whites to 12·25 in the purple-topped swede, or more than 5½ per cent.; but there is little doubt that it is dependent on the variety of plant, rather than upon any effects of manure or culture.

As a general inference from our results, we may state that the mineral and carbonaceous manures, which we have before seen to favour bulb-formation,—that is, to determine to an early maturity, are those which in a given time will yield the largest percentage of dry matter in the bulb; but nitrogenous manures, on the other hand, which when in excess do not enhance bulb-formation (a process of deposition), but rather an extension of the leaf or more vascular system of the plant, involving a prolonged tendency to active circulation, and consequently a higher amount of vehicular watery fluid in proportion to fixed substance, will afford a smaller percentage of dry matter in the produced bulb.

Were we, assuming bulb-formation to succeed leaf-formation, to judge from some analogy furnished by other plants, we might expect that the earlier organ, the leaf, would contain a less percentage of dry matter than the later one, the bulb; but inasmuch as the dry matter is frequently about twice as great in the former as in the latter, any such reasoning would imply a wrong conception of the physiological relationship of the two organs.

We regret that the entire series of leaves of this 3rd year of our experiments was not collected for drying, and that indeed none were taken until after the first weighing of the crops, a few weeks later than the specimen-bulbs were gathered. We shall not, therefore, employ the results for any more important purpose than to show how far the effects of manures are the same in kind as in the case of the bulbs, determining to the *depositing* or to the more *circulatory* tendencies of growth.

Here again we find no considerable variation, yet sufficient in amount and in uniformity to render the mean results reliable for our present purpose. The plants by mineral manures alone, in the first column, which were the furthest advanced in maturation

PERCENTAGE of Dry Matter in Norfolk White Turnip Leaf.

Plot Numbers.	Description of Drilled Manures.	Drilled Manures only.	Drilled Manures, and Top-dressing of Sulph. Am.	Drilled Manures, and Top-dressing of Rape-cake and Sulph. Ammonia.
9	400 lbs. calcined bone-dust, hydrochloric acid = 268 lbs. sulphuric acid	13·63	13·23	12·57
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	13·93	13·19	12·74
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, and 157 lbs. pearlash	13·79	13·48	13·46
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid	13·33	13·12	12·68
22	11 cwts. superphosphate of lime	13·97	13·55	12·91
	Mean results	13·73	13·31	12·87

(or almost past that point), give the highest percentage of dry matter in the leaf as well as in the bulb. Those under the addition of ammoniacal salt give in the leaf a percentage uniformly, but not so far relatively lower as in the case of the bulbs; but it must be remembered that the leaves were gathered much later, and indeed, when, in these cases as well as in those by the purely mineral manures, the point of maturity and exhaustion of soil-supplies for organic food had been approached, or past. We find again that the more vigorous plants under both rape-cake and ammoniacal salt have, coincidently with the greater prevalence of vascular action, a less percentage of dry matter.

Whilst we are writing, the specimens of the present season's growth are being operated upon in the drying bath, but as we have not given any account of our experiments since 1845, we need only say that succeeding results indicate the same general facts on the subject of dry matter as those to which we have drawn attention.

Having argued that, supposing the dry matter in the turnip were of uniform composition, a high percentage can only indicate the amount of solid substance in a given amount of produce at the period of growth at which the determination is made, and does not by any means unconditionally show the efficiency of the manures employed, we shall turn our attention to the composition of the dry substance itself. It has been stated that dry vegetable produce contains the so-called *vegetable* or "*organic*" constituents, and the "*mineral*" or "*inorganic*," the latter being that portion which remains after the former is burnt away.

We shall first speak of the composition of the organic or vegetable part of the turnip, and shall endeavour to show its dependence on the manures by which the plant is grown, and the probable relative feeding values of different specimens.

We do not pretend to have reached further than the threshold of this inquiry, but still hope our results may furnish some interesting inferences. The organic matter of the turnip-bulb is composed of several complex bodies, some of which consist of carbon, hydrogen, and oxygen, whilst others contain nitrogen in addition to the other three elements. Other substances, such as sulphur and phosphorus, are also found in these compounds, but in small quantities, and their presence or absence is immaterial to us just now.

Those of the compounds which contain nitrogen are in less proportion in plants than those in which it is absent; but nitrogen is a very important constituent in all food, so much so indeed that the comparative feeding value of different articles of produce may frequently be estimated by the amount of nitrogen they contain; and we shall, to some extent, act upon this assumption in what we are about to detail.

Those who have read the paper on Agricultural Chemistry in the last number of this Journal, will bear in mind the remarkable fact there indicated, that the larger the amount of the nitrogen supplied by manure for the growth of wheat, the less was the percentage of that substance in the produced grain. This is not consistent with the views generally maintained on this subject, but it seemed to us not only sufficiently proved by our experiments—but, when it was remembered that wheat-grain was peculiarly a *starchy* seed, and that starch contains no nitrogen, it was thought that whatever tended to the healthy action of the plant (as nitrogenous manures were found to do) would of necessity develop the special aim and products of the plant, and that in fact it was more natural to expect that the seed would under these circumstances be more *starchy* than that it would be more nitrogenous and less starchy. In growing *wheat-grain*, then, by means of *nitrogenous* manures the *percentage* of nitrogen in the produce was rather diminished than increased. The following results will show whether a similar effect is observed in the growth of turnip-bulbs:—

This is not the place to give any detailed account of our methods of analysis, but we may say that we think considerable confidence may be placed in the results, as a comparative series; and we believe them to be, moreover, not wide of the exact truth. If we had to give an opinion, however, as to the probable direction and extent of any error, we should suspect it to be in defect rather than in excess, and that if it exist it is pretty uniform throughout

PERCENTAGES of Nitrogen in Dry Turnip Bulbs, the produce of different Manures.

Plot Numbers.	Description of Drilled Manures.	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
9	400 lbs. calcined bone-dust, hydrochloric acid = 268 lbs. sulphuric acid	1·46	1·93	2·82	2·22
22	11 cwts. superphosphate of lime ..	1·58	1·89	2·89	2·44
	Mean results	1·52	1·91	2·86	2·33

the series; that its probable extent is 0·10, and its utmost range 0·20. Should such general deficiency pervade our results, it is dependent partly on the fact that succulent specimens cannot be fully dried in air at 212° without some loss of nitrogen, and in part also upon certain practical difficulties attending the conduct of the determination of nitrogen in substances in which the actual percentage is so small as in the instances before us. We may add that each of the results given in this paper is the mean of two determinations at least, and when there has been a difference of 0·10 a third has always been made.

Referring to the results of the table, and taking the columns separately, we see a very marked coincidence between the figures in each, and as marked a contrast between column and column; and if we call to mind the peculiarities of the several organic conditions of manuring, we shall see the influence of the nitrogenous supply to be exactly opposite to that observed in the case of wheat-grain, and in fact that the percentage of nitrogen in the turnip-bulb bears a direct instead of an inverse relation to the predominance of that substance in the manure.

Thus, in the instances quoted, the percentage of nitrogen in the dry substance of the produced bulb is by mineral manures alone 1·52; by the addition of rape-cake, which contains, besides a large amount of carbon, a considerable quantity of nitrogen, we have 1·91 per cent.; by ammoniacal salts, supplying abundance of nitrogen, but no carbon, 2·86 per cent.; and when to this exclusive nitrogenous supply rape-cake is superadded, we have 2·33 per cent. There is here seen, then, very evident connexion between the percentage of nitrogen in the substance of the bulb, and the supply of it in the manures employed. It is worthy of remark, however, that it is not the actual acreage quantity of nitrogen, but its proportion to other constituents that is so clearly *indicated*. Thus, in the third column, with an acreage supply of

about 60 lbs. of nitrogen by manure, we have a percentage of 2·86 in the dry matter of the produced bulb, whilst in the fourth column, with a supply of about 110 lbs. per acre, we have only 2·33 per cent.; but when we remember that in the latter case there was a large amount of carbon in the manure, and in the former none, we have a clear illustration of the close connexion between the provision by manure and the composition of the produce. To render our meaning more intelligible we may further explain that the nitrogen in the turnip, and indeed in food-products generally, exists in combination with carbon, hydrogen, and oxygen, itself comprising nearly one-sixth part of the thus constituted nitrogenous compound; the remainder of the dry matter consists of the compounds destitute of nitrogen, of which the chief constituent is carbon. Now in column 3 there was no carbon in the manure, but in column 4 a large amount was provided in the rape-cake, and notwithstanding that there was in this case not only the same amount of nitrogen supplied by ammonia salt as in column 3, but further, all that of the rape-cake, raising the total amount to nearly double, yet the supply at the same time of carbon, favouring the formation of non-nitrogenous compounds, gives a less proportion of those which are nitrogenous.

Again, if we compare the mean of these results with the mean percentage of dry matter under the four conditions of manuring, we find with the lowest percentage of nitrogen in the bulb the largest amount of dry matter, and with the highest percentage of nitrogen the lowest amount of dry matter. There is then with the highest percentage of nitrogen more of circulating fluid and less of fixed deposited substance than with the lowest; and since there was, moreover, not only a less matured bulb, but a less acreage produce of it in a given time than where the nitrogenous supply was less, we are led to infer that the high percentage of nitrogen indicates a relative deficiency of carbonaceous substance, rather than a favourably increased amount of nitrogen. Indeed, these results will confirm the opinion already urged, namely, that turnip-bulb formation is very dependent on an abundant supply of *carbonaceous matter to the roots*, and that the more the nitrogenous condition of manuring prevails over the carbonaceous, the more will vascularity and the less will special deposition be enhanced. Thus the highly vascular seed-forming turnip-plant is to the less vascular bulb-forming one, as the well-conditioned breeding or working animal is to the stall-fed fatting one; a considerable amount of nitrogenous as well as carbonaceous food is essential to both of these; in the one case, however, exercise tends to consume what in the other increases the bulk of the animal: so that whilst the food taken may indeed in the two cases be very similar, yet the balance of it retained in

the animal will be as different as, in the cases of the two plants, is attained by more directly varying the supply, and the peculiar habits of life and growth will be developed accordingly.

The following results further show how truly dependent is the composition of the turnip-bulb upon the provision by manure:—

PERCENTAGES of Nitrogen in the Dry Matter of Turnip Bulbs, the produce of different Manures.

Plot Numbers.	Conditions of Standard Manuring.	Standard Manures only.	Standard Manures, and Top-dressing of Rape-cake.	Standard Manures, and Top-dressing of Amm. Salt.	Standard Manures, and Top-dressing of Rape-cake and Amm. Salt.
1	12 tons farm-yard dung	1·56	..	2·54	..
2	Unmanured	3·31	2·17	2·98	2·53
3	8 cwts. rape-cake	2·23	2·79	2·80	3·00

We see that the percentage of nitrogen by farm-yard dung is 1·56, which differs little from either the results obtained by mineral manures alone, when all the organic supply was derived from normal sources, or from the number observed by Boussingault, which was 1·70. The addition of sulphate of ammonia to the farm-yard dung, raises the percentage of nitrogen in the bulb from 1·56 to 2·54, or by two-thirds of the usually observed amount. Here, however, we have in the manure a large provision of carbonaceous matter, and, as before noticed, a coincidently less percentage of nitrogen than when there was ammoniacal salt alone.

In the second line of the table we have some most interesting results, consistent with what have gone before, and, further, affording a new and significant illustration of the office of the turnip as a *fallow-crop*.

It will be recollected that the average weight of the bulbs on the unmanured plot was, in this season of 1845, less than 2 oz., and that the entire produce was only 13½ cwts. per acre. We find, however, that these stunted bulbs give a percentage of nitrogen higher than any in our series, even than those which had an unusually excessive supply by manure, and twice as high as the amount supposed generally to exist in the cultivated bulb. We may reasonably infer that, under the influence of season and a soil reduced to the lowest conceivable state of exhaustion, as regards its fitness for the growth of the cultivated turnip, the natural supply of nitrogen was, in proportion to that of other constituents, abundantly available to the special accumulative powers *of the plant.* In the same line we find, in the second column,

that the supply of a top-dressing of rape-cake to this otherwise exhausted plot, raises the acreage produce of bulb from 13½ cwts. to 7½ tons, and the average weight of bulb from less than 2 to nearly 11 oz., and notwithstanding the nitrogenous supply of the rape-cake, we have, with its large provision of carbonaceous substance, the percentage of nitrogen reduced from 3·31 to 2·17. In the 3rd column, where there is added to the natural supplies of soil and season nitrogen, but *no* carbon, we had an evidently unhealthy condition; for the acreage produce, the size of bulb, and the number of plants, were all less than where there was no manure whatever. Again, with these unfavourable circumstances of growth we have a very large percentage of nitrogen; less, indeed, than in the unmanured bulbs, but considerably higher than when rape-cake alone was used. In the 4th column we have the same supply by manure of carbon and nitrogen as in column 2, with the addition, however, of the nitrogen as in column 3, and we find, as in other cases, that although the actual supply of nitrogen is greater than in column 3, it being proportionably less, the percentage in the bulb is reduced.

In the third line the standard manure is rape-cake, the extra dressings being, as usual, a further addition of rape-cake, of ammoniacal salt, or of both. Comparing the percentage of nitrogen by the drilled rape-cake, as in column 1, with that by farm-yard dung, we find that the rape-cake gives the highest, and we would suppose the proportion of nitrogen to carbon would be greater. In column 2 the amount of rape-cake being greater, the percentage of nitrogen is greater: the *supply* of nitrogen to that of carbon is not, however, greater than in column 1; but we have before seen that a full quantity of rape-cake, without extra mineral manure, is not conducive to the most healthy growth of the turnip-bulb; nor indeed would the carbon so supplied be so completely and rapidly available as the nitrogen. The addition of ammoniacal salt, in column 3, raises the percentage of nitrogen from 2·23 to 2·80, and in column 4, as compared with column 2, from 2·79 to 3·00.

We have made other determinations of nitrogen in turnip-bulb, with a view to some more special points, but as we cannot discuss them in this paper without extending our remarks to an undue length, we shall defer notice of them until a future occasion. The results already given are, moreover, we think, sufficient to aid our estimation of the characters of the turnip as a food and rotation crop.

An important fact elicited is, that within a certain range, which indeed is wider than has generally been supposed, the organic composition of the turnip bears a very direct relation to that of the manures by which it is *grown*. It is seen that the proportion

of nitrogen usually found in the cultivated turnip-bulb may be nearly doubled by means of ammoniacal manures, and since we have stated that the feeding value of a crop may to some extent be measured by its percentage of nitrogen, it might be supposed that we should be led strongly to advocate the use of such manures in the growth of the turnip. Our field experiments have already shown, however, that this would be a one-sided inference from these departmental results; and when we come to make some general application of our varied evidence to practical and economic agriculture, the true position and bearing of the different branches of the question will be indicated.

We regret that we have not as yet a sufficient number of determinations of nitrogen in the turnip leaf to enable us to decide satisfactorily whether the percentage be as clearly dependent upon the supply by manure as in the case of the bulb; the vigorous leaf being, however, highly vascular, and containing much of the still circulating unassimilated food derived from the soil, we might anticipate it would be so; but, on the other hand, if we look at the bulb as a reservoir of matters which are in excess so far as the natural seed-forming tendencies are concerned, we might expect the less artificial organs, the leaves, would be more constant in their composition. The following results will not assist us much in deciding these questions; they are, however, not without interest:—

PERCENTAGE of Nitrogen in the Dry Matter of Norfolk White Turnip Leaf.

Plot Numbers.	Description of Manures.	Dried at 212°.	Specimen dried below 200°, and Nitrogen calculated upon fully dried Substance.
1	Farm-yard dung ..	3·24	3·60
2	Unmanured	4·22	4·35

Here are given the results obtained from specimens of leaf, in one instance dried fully at 212° in the water bath, and in another dried much below that temperature; the percentage of nitrogen in this case being calculated upon the fully desiccated substance. The fact before alluded to, that succulent specimens frequently lose nitrogen at 212°, is thus illustrated; in one instance there is a defect of 0·36, and in the other of 0·13. We have met with a similar result with other succulent substances.

It will be remembered that the turnip-leaf was found to contain a proportion of dry matter more than half as large again as the bulb; and it is seen that in the case of the dung specimen the dry

matter of the leaf has a percentage of nitrogen twice as high as that of the bulb. A given weight of the fresh leaf would therefore contain more than three times as much nitrogen as an equal amount of bulb. Since, however, the bulk of the leaves at the time the turnip crop is gathered or consumed are past the condition in which our picked specimens were taken for analysis, it would be unsafe to employ these results for purposes of acreage calculation; yet they are in other respects to be relied upon.

Comparing the characters of the cultivated with those of the uncultivated plants, as shown by the analyses which have been given, we observe the decrease by cultivation in the percentage of nitrogen in the dry matter is in the leaf only ·75, but in the bulb 1·75; from which, again, we may perhaps gather that the cultivated bulb is the result of a continued accumulation of *secreted* matters, formed in quantity beyond the essential requirements of the plant as such: the leaf, on the other hand, containing, besides its own special structures and products, little more than those substances derived from *immediate* supply,—has, therefore, a composition in a less degree varying according to the constant circumstances of growth, but comprising a larger proportion of unsecreted matter.

The fact that, notwithstanding the large nitrogenous contents of turnip-leaves, they should only be to a small extent valued as food, doubtless arises from the large amount of matters which they contain only brought within the range of the organism, themselves as yet unorganised, and existing as saline and other changeable fluids, to which we may readily attribute a medicinal and purgative, rather than a direct nutritive effect; elaboration to some extent being, as we are aware, an important element in the condition of food for animals. The low degree of stability in some of the nitrogenous contents of succulent substances, as indicated in the drying process, as well as our conceptions of the offices and physiological position of the different parts of a plant, bespeak, indeed, that where an active circulation is still proceeding, there will be found not only the actual and fixed, but also the prospectively possible constituents, the latter as yet only in a vehicular condition, and little influenced by the selective and appropriative powers of the organism. It is true that the varying character of the vital apparatus of different animals adapts them to the use of vegetable food in varying degrees and states of elaboration; but there seems to be a point in this degree of elaboration below which constituents lose their food-qualities; or even, it may be doubted whether, in such cases, the matters are not really as little truly vegetable as would be the watery extract of the soil as it is taken up by the rootlets, and from the condition of which little deviation has hitherto resulted from the vital actions of the plant.

Such substances, indeed, may perhaps be considered as still belonging to the mineral kingdom, upon which animal life cannot be sustained.

Referring to the more special lesson of the experimental results last given, we notice, that whilst the leaf grown by farm-yard dung contains 3·60 per cent. of nitrogen in its dry matter, that grown without manure of any kind in a turnip-bulb exhausted soil has 4·35 per cent.; and it will be remembered the bulbs corresponding to these specimens of leaf give respectively 1·56 and 3· 31 per cent. We have, then, in the leaf as well as in the bulb, a larger proportion of nitrogen in the more natural but agriculturally useless turnip than in the cultivated one; and if we are right in considering that, within certain limits, the composition of a succulent imperfectly elaborated vegetable will bear some direct relation to the supplies of food within its reach, we must conceive that there was, independently of art, a resource of nitrogen available to the uncultivated plants far beyond that of other necessary constituents. If, then, the powers of reliance upon normal supplies of nitrogen here observed are to be fully developed and turned to economical account, it is more especially by means of an artificial provision of the other constituents that this object will be attained.

We think that in these facts we have a beautiful illustration of some of the physical and physiological characters upon which depend, materially at least, the economic value of the turnip in rotation with corn. The true *economy* of alternate cropping, whilst, however, it is intimately associated with functional differences, such as we have shown to exist in the selected plants, yet depends much also upon the destination and uses of the produce, independently of which, the peculiar accumulative tendencies of the different crops could not be rendered profitably subservient. We shall not, however, consider the connexion between the various sources of the economy of a rotation of crops, until, having detailed all the evidence which it is our intention to bring forward, we come to sum up and apply our departmental results to the practice of agriculture.

We shall now give some account of the mineral substances found in the turnip. Our experimental results referring to this branch of the question are very numerous, and it was our wish to have considered them somewhat fully; but as our permitted space is already nearly exhausted, we must defer doing so until a future opportunity, and confine our remarks on this occasion to some explanation of the nature of the subject, and to indicating the general bearing of our evidence upon the conclusions which have been arrived at in the foregoing pages.

The knowledge which we at present possess of the amount, the composition, and the office of the mineral matter found in combination with the various definite organic compounds of which the solid and fixed substance of a plant is made up, is very limited; yet it is such as by no means leads us to assign to all the constituents of the ash of a crude vegetable product an essential position in the constitution either of the parts already elaborated, or of those which would result from the continued growth of the plant. It is obvious that an examination into the nature and constancy of the circumstances of growth, with which variations in the quantity and composition of plant-ashes are connected, cannot alone provide an explanation of the uses and importance of the mineral substances in the plant; it is, however, an essential step in the inquiry, and the results attained by it must materially direct and aid any collateral course of investigation.

In entering at once upon this part of our evidence, we may again state that we did not determine the amount of dry matter in the produce of the first two seasons' experiments: we are unable, therefore, to give the percentage of ash in the dry matter in the specimens of those two seasons, and it will afterwards be seen that this particular is more significant than that of the percentage in the fresh produce. On this account, and as we wish to compress our matter as much as possible, we shall not give any statement of the results of those two years, but only remark that a close examination of them affords like conclusions to those to which the third season's experiments lead us.

The percentage of ash in the fresh bulbs, the mean of the produce of each of the four conditions of manuring, frequently referred to before, are given below.

General Description of Manuring.	Percentage of Ash in Fresh Substance of "Norfolk White" Turnip Bulb.
Season 1845.—Mean of 13 experiments by purely mineral manures	0·58
Season 1845.—Mean of 13 experiments by mineral manures and rape-cake added	0·57
Season 1845.—Mean of 13 experiments by mineral manures and ammoniacal salt	0·61
Season 1845.—Mean of 13 experiments by mineral manures, and both ammoniacal salt and rape-cake	0·60

These results are the actually found percentages of ash, without any deduction for adventitious substances, such as siliceous matter and charcoal. The figures exhibit very slight differences, such as could not justify any important conclusions, were these

contrary to otherwise probable indications; we find, however, that, slight as the differences are, they are such in kind as other circumstances would lead us to anticipate; and we need only notice that the percentage of ash is seen to be highest where the nitrogenous condition of manuring was predominant, and lowest where the carbonaceous was more characteristic.

The variations are, however, more apparent when the percentages of ash upon the dry, rather than upon the fresh, matter are given. The mean percentage of the dry matter itself, and of its ash, in the specimens last quoted, and of the nitrogen in the dry matter of two of the specimens in each case, are here tabulated:—

General Description of Manuring.	Percentage of Dry Matter in Bulb.	Percentage of Ash in Dry Matter.	Percentage of Nitrogen in Dry Matter (Specimens Nos. 9 and 22).
1845.—Mean of 13 experiments by purely mineral manures	8·34	6·99	1·52
1845.—Mean of 13 experiments by mineral manures and rape-cake	7·97	7·21	1·91
1845.—Mean of 13 experiments by mineral manures and ammoniacal salt	7·41	8·24	2·86
1845.—Mean of 13 experiments by mineral manures and ammoniacal salt and rape-cake ..	7·48	8·08	2·33

The coincidences here brought to view are of considerable interest, and clearly show a constant decrease in amount of mineral matter as the deposition of solid vegetable substance progresses. We have with the highest proportion of dry, the lowest proportion of mineral matter; and with the lowest amount of dry matter, the highest of mineral substances; and even with the slight increase in dry matter exhibited in line 4, compared with line 3, we have a decrease in the percentage of mineral constituents. We can scarcely fail to recognise in these results a marked distinction between those constituents of the bulb which are as yet merely circulatory and unappropriated, and those which are secreted and fixed, the former being indicated by a small amount of dry matter and large amount of ash, and the latter by a large amount of dry matter and a small amount of ash.

The connexion between the amount of dry matter and its percentage of ash being admitted, and that between the amount of nitrogen, that of dry matter, and the condition of maturation having been pointed out before, it is seen that the views taken are fully confirmed by the relation of the ash in the dry matter to that of the nitrogen in the same. Thus we have in the Table, with the most fixed matter and least nitrogen, also the least ash;

and with the most ash and most nitrogen, the least dry matter. The relative tendency to bulbous deposition, or active vascular circulation, under carbonaceous and nitrogenous manures respectively, is here again exhibited.

It will be remembered that the specimens of turnip-leaf which were examined, were gathered very late in the season—the few that could be selected green being taken. All were, however, far advanced in stage of growth, and it was found that, whether owing to an uniformity in the stage of growth, or to the essential tendency of the leaves, as different from that of the bulb, there was very little variation in the proportion of dry matter, compared with that observed in the bulbs. The following mean results will illustrate this:—

Reference to History of the Specimens.	Percentage of Dry Matter in Leaf.	Percentage of Ash in Fresh Leaf.	Percentage of Ash in Dry Matter.
Mean of 9, 14, 18, 21, and 22, with mineral manures only	13·73	1·31	9·52
Mean of 9, 14, 18, 21, and 22, with mineral manures and ammoniacal salt	13·31	1·26	9·49
Mean of 9, 14, 18, 21, and 22, with mineral manures, rape-cake, and ammoniacal salt	12·87	1·25	9·72

The differences here seen are, as we have already implied, small; nor are the results so undoubted in their bearing as most that have been quoted; yet still we have with the smallest amount of dry matter, the largest percentage of ash in the dry matter. The centre column shows the lowest percentage of ash in the *fresh* leaf in this case; but it is of course the percentage to *water*, rather than to dry vegetable substance, that is there indicated.

The comparative ash results that have been given, whether of the turnip-bulb or leaf, lead us then yet again to draw some distinctions between the fixed and the circulating constituents of a succulent plant, and to trace the proportion of these respectively to the stage of maturity of the organ, whilst this has been found to depend greatly upon the supply by manure.

Were we to compare the composition of the leaf, as thus far shown, with that of the bulb, and to attempt to apply on all points the same kind of reasoning as between bulb and bulb, or leaf and leaf, we should at once meet with inconsistencies, for we find in the earlier product of the plant—the leaf—a much larger amount of dry matter than in the later one—the bulb. And again, with the higher percentage of dry matter in the leaf, we have at the same time a much larger amount of ash in that dry matter. Such comparisons are, however, physiologically, quite inadmissible. Looking at the question in another view, however, we have attri-

buted to the bulb, notwithstanding its large amount of water, in some respects a higher condition of elaboration, or fixedness in its solid constituents, than to the leaf. We have, indeed, supposed that bulb formation, in the degree in which it is developed for feeding purposes, is a deposition of matter existing in quantity beyond what is *essential* to the health of the natural plant, much as depositions are known to take place in animals under somewhat analogous circumstances.

The following comparative statement of the proportion of ash in the dry matter of the leaf, the bulb, and the seed of the Norfolk White turnip, will favour the view that the composition of the bulb implies a more advanced selective process than that of leaf:—

	Leaf.	Bulb.	Seed.
Percentage of ash in the dry matter of	9·5	6·9	4·5

There is then, comparing one organ with another, as well as different specimens of the same organ, a diminution in the proportion of the mineral to the organic constituents of the plant the further we advance towards the matured results of the vital process. It is true that even in the seed the amount of mineral substances is greater than our conceptions regarding the composition of the definite compounds of which it is made up would alone have led us to anticipate; but numerous experiments with wheat grain show that, however small may be the differences exhibited in a series of specimens which can be compared with each other in this respect, yet they will indicate the less percentage of ash in the dry matter the higher the percentage of the dry matter itself—that is to say, the more completely ripening processes have been developed. An *excess* of mineral matter in any such case may to some extent therefore be owing to an increased proportion of vascular contents to perfectly elaborated substance.

Admitting that the mineral substances found in the leaves of the turnip and of other plants are such in variety and in amount that we cannot suppose them to be all destined to enter into combination, and actually to constitute a portion of the fixed and essential formations of the plants, yet their presence within it is not on that account quite inexplicable. The experiments of De Saussure and others show that the rootlets of a plant take up the dissolved substances presented to them, exercising but little of selective power, whilst such as they have is rather of a mechanical than of a more purely vital kind. It is not to be wondered at, then, that the composition of the ash of highly vascular vegetable substances should exhibit a wide range of difference, according to climate, manuring, and soil. In such cases a large proportion of

the mineral matters are distributed, not as constituents of the organized substance of the plant, but in its vessels and fluids, owing their quantity and character, to a great extent, to the external influences just referred to, but little, comparatively, to the selective processes of the organism.

The following mean results of analysis seem to show that the more the truly vital processes have been exercised, the more *special* does the composition of the mineral matter become:—

	Leaf Ash. Mean of 24 Analyses by Mr. D. Campbell.	Bulb Ash. Mean of 24 Analyses by Dr. Gilbert.
Potass	22·05	44·84
Chloride of potassium	4·84	0·34
Soda	0·19	1·79
Chloride of sodium	6·15	6·86
Lime	30·53	11·40
Magnesia	0·82	1·46
Phosphoric acid *	5·05	7·89
Sulphuric acid	12·55	10·63
Carbonic acid	17·82	14·79
	100·00	100·00

These results being the mean of so many analyses as twenty-four in each case, the general character of the distinctions they exhibit may be fully relied upon. It is to be regretted that we have not an actual analysis of the ash of the seed of the Norfolk White, to place by the side of those of the leaf and of the bulb. We know, however, that phosphoric acid, potass, and magnesia are eminently seed-ash constituents, and that the existence of the vehicular element, chlorine, in a *perfectly ripened* seed is doubtful. The increase in the percentage of the more special, and decrease in that of the less special constituents, is clearly shown in the results given above, as we proceed from the earlier formation to the later one, the composition of which is more influenced by the peculiar elaborative action of the organism. Of the soda salts, indeed, the actual amount is somewhat larger in the bulb than in the leaf, but their proportion to the potass ones is much less.

It has been observed that the ash analyses of green crops seem to afford confirmation of the much discussed theory of the substitution of potass by soda in plants, but that those of grain crops, on the other hand, do not serve the same purpose. It seems to us, however, that if in green and succulent substances, in which

* In the analysis of the leaf and bulb ash, the phosphoric acid is calculated from the bone-earth precipitate, taking no account of the small quantity of iron salt usually present.

there exists a considerable amount of matter admitted by the roots, with but little of special selective power, the proportions of potass and soda may vary according to the variations in the soluble contents of the soil, but the further we advance towards the ultimate results of the organism, the larger is the proportion of potass to soda; there is in such a fact evidence against the supposition that the vegetable organism can substitute the one alkali for the other, for in the case assumed soda would seem to be present only *before* the *vital* selective processes had been exercised upon the matters brought within their sphere of influence. If, then, the theory referred to suppose a replacement of potass by soda, as an actual constituent of vegetable products, we think that facts hitherto observed are such as should tend to disprove rather than to prove its validity. On the other hand, we may well believe that the large amount of mineral matters admitted into a plant, beyond that which is likely to become fixed and combined with its structures or deposits, has, nevertheless, some office to perform. We know too little, however, of the means employed by the vital processes to enable us to assign special agencies to special substances; yet the presence of mineral matters not actually to take part as constituents, is by no means improbably of essential importance in determining the changes to which the circulating juices of the plant are subject; nor is it impossible that in such an office as this soda may substitute potass, and one acid another, that is to say, as *agents*, if not as constituents. It is, indeed, only by supposing some other requirement in the plant than that of mere provision of actual constituents, that we can in any degree account, either for the extraordinary effects which a large supply of mineral substances is in some cases found to produce, or for its possession of the power by virtue of which so large an amount of such substances is taken up by its roots and distributed throughout its living organs.

It was our intention to bring forward many more results, both of the field and laboratory, relating to the important subject of root-culture, had our space permitted it. We have still eighty analyses of ashes obtained from turnips, the history of the growth of which is detailed in this paper. It would also have been advantageous to give, in less technical language, a short summary of the results arrived at in the course of these experiments, for the convenience of those readers who are more conversant with practical than with scientific agriculture. Having, however, through the kindness of the Journal Committee, already extended our article to a length beyond what is usually allotted to contributors, we must conclude *with a* brief explanation of the means to be employed in the pro-

fitable cultivation of roots, and of the peculiar properties which they possess, and which constitute their value as fallow-crops.

A practical farmer, accustomed to consume his turnips upon his land every fourth or fifth year, might be inclined to doubt the correctness of any conclusions drawn from a set of experiments so artificial as the removal of five successive crops of turnips from the same field. It should therefore be distinctly understood that the object of these experiments is not to provide any examples for direct imitation in practice, but to enable us to ascertain the real characters of season, soil, and manuring required for the growth of the turnip, in order that, the principles of its culture being better understood, the practice of it may be more economically carried out.

In our experiments upon wheat, given in the last number of this Journal, we showed that the produce of grain, beyond that which the soil and season gave in successive years, was dependent upon the supply of nitrogen; that 100 lbs. of rapecake, containing 5 lbs. of nitrogen and 80 to 90 lbs. of carbonaceous matter, gave no greater increase of corn than a salt of ammonia containing 5 lbs. of nitrogen and no carbonaceous matter; and that the produce from 14 tons of farm-yard dung upon the same space of ground year after year was invariably less than that which was obtained from 2 cwts. of ammoniacal salts. The farm-yard dung and rape-cake increased the produce of grain in proportion to the amount of nitrogen which they contained; but as the rape-cake contains only 5 per cent. of nitrogen, and dung frequently not a ½ per cent., or one pound in 200, to what purpose can this bulk of carbonaceous matter be applied? As long as corn is cultivated, it is evidently of little use.

Our experiments upon turnips answer this question in a most satisfactory manner. They show distinctly that the production of turnip-bulb depends upon the supply of carbonaceous matter in the soil, and that the true office of the turnip and other root-crops consists in converting the otherwise useless refuse of our corn-crops (straw) into a succulent and nourishing food for animals. During the five years over which our turnip experiments have been carried, in only one instance has the acreage weight of bulbs reached 17 tons. We know that the mineral matter required by the turnip has not been deficient, and in many instances very large quantities of nitrogen have been supplied; but the essential substance, carbonaceous matter, required for bulb-formation, has been but moderately supplied in the form of rape-cake; in one instance, where it was supplied in a larger quantity by dung, the greatest produce was obtained. Having, therefore, shown that to obtain heavy crops of bulbs, large amounts of carbonaceous matters should be supplied

to the soil, and that dung is the cheapest source of this substance, the question next arises, What are the best substitutes for it?

Dung is an article in which our farm-yards are very apt to be deficient. It might be supposed that if sufficient carbonaceous matter were once accumulated upon a farm exporting only corn and meat, the loss in these two products would not be greater than would be supplied in return by the atmosphere; but the experiments of Boussingault and Dr. R. D. Thomson show that the amount of such matter respired by an animal, and therefore lost to a farm, is very great; indeed we should not be far wrong if we said that in feeding a crop of turnips by stock one-half of the carbonaceous matter in it is lost to the farm. To restore the loss of organic matter most economically, various processes are recommended: some advocate the consumption of artificial food with the turnip; some the employment of ammoniacal manures in order to collect carbon from the atmosphere; and some maintain that if the mineral substances composing the ash of the turnip were restored to the soil, it could supply itself with organic matter.

To commence with the mineral manures:—Analysis has shown that a great portion of the ash of the turnip consists of the alkalies, potass and soda, and of magnesia—and these substances have been recommended in the formation of mineral manures; we think, however, that a careful examination of the position which the turnip-crop holds in a rotation, and the manner in which its organic and inorganic matters are applied in farm practice, will show that the artificial supply of alkalies can rarely, if ever, be advocated. A fair crop of turnips would contain in leaf and bulb about one ton and a-half of dry matter, of which 250 lbs. would consist of minerals. Omitting those minerals which are of less importance to consider here, we may take the composition of the crop as follows:—

Dry organic matter	3110
Potash	127
Phosphate of lime	50
Sulphate of lime	40

Of the organic matter, more than one-half of the carbon, but probably scarcely one-fourth of the nitrogen, is lost to the farm by the respiration and increase of the stock.* The amount of phosphate of lime removed would vary greatly with the nature of the stock consuming the turnips. A breeding flock or young growing animals abstract large quantities to be employed in the production of bone, while full-grown animals require very much less. Of the alkalies contained in the ash of the turnip the stock return to the soil nearly all they take up. Barley generally

* This *retention upon the farm, of nitrogen specially*, demands more notice than our space permits.

follows after turnips, the greater part of the corn being taken to market. A crop of 40 bushels carries off phosphoric acid equal to about 28 lbs. of phosphate of lime, and 9 lbs. of potash. The clover following the barley, being consumed by stock, causes a further loss to the farm of organic matter and phosphate of lime, but of little or no alkalies; while the wheat-grain removes about 12 lbs. of potash and 30 lbs. of phosphates.

We see, therefore, that much of the organic matter of the turnip is lost to the farm by respiration, and the phosphate of lime largely in the formation of bone; while the export of potash is so small that the quantity contained in one acre of turnips would not be entirely exported under twenty years. It is clear, then, that unless by actual waste, there is, under an ordinary course of farming, without the use of imported food, a comparatively small decrease in the amount of available alkalies in the soil; but when we consider the vast amount of alkalies existing in the soil itself, and set free by annual decomposition, and that in every well-cultivated farm there will be a considerable quantity imported in cattle food, there can be little doubt that, under ordinary circumstances, the available alkalies accumulate in the soil. It may be further remarked, that in our experiments the alkalies, in whatever form we applied them, were always injurious to the vigorous growth of the young plant. Although the export of phosphate of lime from a farm is very much larger than that of the alkalies, the continual use of it as a manure for the turnip-crop could not be advocated upon the ground of mere exhaustion; for it could be proved that where the supply of it to the turnip-crop during successive years has been much greater than what has been removed in produce, the effects of further applications were equally successful.

We are therefore inclined to limit the economical application of mineral manures to phosphate of lime alone, and even then in most cases it is employed, not as an element of which the soil generally is deficient, but as an agent for promoting to a remarkable degree the early and vigorous development of the young plant within a limited range, and carrying it with rapidity over those stages, any delay in which is attended with great injury, and often with the destruction of the whole crop.

The sources of phosphate of lime are guano, bones, and the compound of phosphates and sulphuric acid, called superphosphate of lime. The latter manure is the form which is found to produce the greatest effect upon the young plant, and especially upon the development of a large amount of fibrous roots. Although strongly acid, it may be drilled with the seed without the slightest injury to it.

It must, however, be clearly understood that the bulk of an

agricultural crop of turnips depends materially upon the amount of organic matter contained in the soil, without which the development of the power of growth by means of the phosphate will be unavailing. The first application of a mineral phosphate is liable to produce heavier crops of turnips than those which follow, unless the carbonaceous matter taken from the soil by the turnips, and lost by the respiration of the stock consuming them, has been made up by imported cattle food. Rape-cake, as containing a large amount of organic matter, is an admirable manure for the turnip as a substitute for farmyard dung; it may be employed in conjunction with superphosphate of lime—the former being sown broadcast, and the latter drilled with the seed.

Peruvian guano, which contains a large quantity of ammonia as well as phosphates, is found to be a much more certain manure for turnips in Scotland, where the fall of rain is large, than in those parts of England where it is much less. Indeed, the natural agencies of *season* are much more favourable to the growth of turnips in Scotland and the north and west of England than in the eastern counties, where the application of skill and capital, upon a soil well suited to the plant, has gained for them a high reputation. In the south of England, and wherever the comparatively small amount of rain that falls renders the production of the turnip-crop uncertain, the cultivation of the mangold-wurzel might be extended with considerable advantage: it can be sown sufficiently early in the spring to enable it to extend its roots deep in the soil before the dry weather sets in, it is not liable to injury from insects, and it is capable of producing a larger amount of solid food than any other crop in a rotation. The objection raised against it as an exhausting crop arises partly from the small amount of produce which it yields from a given weight of manure compared with turnips; but as the percentage of dry matter is greater, the objection may not be valid. The following Table shows the amount of dry matter contained in various root-crops grown this season upon Rothamsted Farm under ordinary cultivation:—

Percentage of dry matter in		Long Red Mangold-wurzel ..	12·7
,,	,,	Yellow Globe ,, ...	11·34
,,	,,	Common Swede (name unknown)	12·2
,,	,,	Skirving's Swede, purple top ..	9·4
,,	,,	,, ,, green top ..	9·4
,,	,,	Green common Turnip	7·9
,,	,,	Norfolk White	7·83

We see by this table that 10 tons of mangold-wurzel contain as much dry matter as 15 tons of white turnips, and that the dif*ference in bulk* between a crop of Skirving's, compared with one

of the older sorts of swedes, is due to the difference in the proportion of the water. That the soil on this farm, although not a turnip soil, is capable of producing good root-crops, *under a proper supply of manure*, may be inferred from the fact that this year, which is anything but a good turnip season, an acre of swedes was weighed, the bulbs of which gave 20 tons 10 cwts.; number of plants per acre, 20,120; average weight, 2 lbs. 3 oz. Ten of the largest were found to weigh 112 lbs.

We found in our experiments that the usual percentage of nitrogen could be nearly doubled by the use of ammoniacal manures; but we do not recommend the general *direct* use of such manures for turnips, notwithstanding that the value of our produce as food depends much upon the percentage of nitrogen it contains.

On some future occasion we shall endeavour to show that, excepting rape-cake, the manures in the market containing nitrogen are more advantageously employed for clover, and other crops of the like kind, than in any other place in the rotation.

If a proper quantity of imported food be consumed upon a farm, the direct supply of nitrogen to the turnip crop by means of artificial manures will certainly not be necessary. An *excess* of nitrogen in the soil produces too large a proportion of leaf, and too little tendency to form bulb. It is true that a crop of turnips having a large proportion of leaf will give a larger amount of manure to the land; but its yield of food will be comparatively small. But, since the manure obtained in such a case previously existed in the soil, the economy of the crop, even so far as its manuring influence is concerned, may be doubted. In fact, so far as our experiments upon this subject enable us to judge, we believe that where the supply of nitrogen to the soil is very great, the amount of it collected from the atmosphere is less, and thus a part of the benefit of the crop would be lost. All the specimens in which we found a high percentage of nitrogen were those in which there was a great development of leaf with a comparatively small tendency to form bulb; and we believe that the high percentage was due to a deficient accumulation of carbon by the plant. Whilst, then, a high percentage of nitrogen may indicate an abundance of it in the soil, the growth of the plant has been in other respects defective. It is probable that the full-grown bulb of such a plant as has only a due proportion of leaf will seldom have a percentage of nitrogen much higher than that which has been usually observed; for with an increased supply of nitrogen there is an excessive production of leaf, and a bulb which, though richer in nitrogen, is not profitably developed. There is, however, a casual advantage in having a somewhat full supply of nitrogen in the *soil for those of our* turnips which are to be eaten

late in the season; for the plants so grown, whilst they may have a less favourable proportion of bulb, yet, owing to the increased vitality and hardiness which result from the nitrogenous manure, the bulb is better fitted to stand the winter temperature without injury. A sufficient importation of food for stock will, however, render the purchase of nitrogenous manures for the turnip crop quite unnecessary; but where such manures are employed, rape-cake will be found to afford a sufficient, and in other respects the most advantageous, means of supply.

Lastly, it must not be forgotten that the tillage of the soil constitutes a most essential element in turnip culture; and that he who sows his turnip-seed upon a badly-cultivated soil is only throwing away his time and money. The naturally light and porous nature of a *turnip soil* points out what are the requirements of these plants; and when the necessary degree of tilth has been obtained, and the seed sown, the introduction of air beneath the surface of the soil by means of the horse and hand-hoe cannot be too frequent; for it is useless to place a large amount of dung in the soil to be converted into the substance of the turnip, unless the free action of the air is provided for at the same time, by which alone the decomposition of the dung can be effected.

J. B. Lawes.

Rothamsted, November, 1847.

Note.—In placing my name to this article, I must observe that whatever merit may be assigned to it is mainly due to the skill and talents of Dr. Gilbert, upon whom the responsibility attending the investigation has devolved. Those who have endeavoured to conduct with accuracy only a few experiments in agriculture will be capable of forming some estimate of the labour which so extensive a series requires.—J. B. L.

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EXPERIMENTAL INVESTIGATION

INTO THE

AMOUNT OF WATER GIVEN OFF BY PLANTS

DURING THEIR GROWTH;

ESPECIALLY IN RELATION TO

THE FIXATION AND SOURCE OF THEIR VARIOUS CONSTITUENTS.

By J. B. LAWES,

OF ROTHAMSTED.

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AMOUNT OF

WATER GIVEN OFF BY PLANTS

DURING THEIR GROWTH.

Of the several natural orders of plants which yield food to man, or to the animals destined for his consumption, or other use, perhaps the most important, both as to the extent of their distribution and the amount of the products they supply, are the *Graminaceæ* and the *Leguminosæ*. There are others, however, to which we are indebted for the roots and tubers, the extended cultivation of which, in alternation with corn, so prominently characterises at least the national agriculture of the present day. The corn-plants of most extended utility in the Leguminous family are the *Bean* and the *Pea;* but we owe to it also some of the most important of our fodder-plants, such as *Clover*, *Trefoil*, *Vetches*, and others. The Graminaceous family, on the other hand, supplies us with *Wheat*, *Barley*, *Rye*, *Oats*, *Rice*, *Maize*, the *Sugar Cane*, and others, besides the natural grasses of our meadows and pastures.

Between these two great natural orders of plants there are, however, many striking and obvious points of contrast as to habits, structure, and products, whilst the vastly different positions allotted by experience to the individuals which they respectively comprise in a system of alternate cropping, are such as clearly to indicate that the resources of their growth are also widely different; and it has been maintained that an explanation of them is mainly to be found in the varying mineral composition of the crops. The scattered observations, however, of many experimenters, and some of not very recent date, would seem to favour an opposite view of the question, and the vastly accumulating published results of the last few years lend an ample confirmation in the same direction.

For our own part, an extensive and systematic series of experiments, conducted both in the field and in the laboratory, leaves not a doubt in our mind that, in the ordinary practice of agriculture in Great Britain, the *exhaustion* which is suffered is prominently connected with a deficiency of "*organic*" or primarily

atmospheric, rather than the "*mineral*" or, more properly, *soil*-constituents; and especially that the supply of NITROGEN, *relatively to other constituents*, is defective. We have already, in the 'Journal of the Royal Agricultural Society,' indicated some striking facts bearing upon this point, in the discussion of the results of some of our experiments upon the growth and composition of Wheat and of Turnips. Beans, Peas, and Clover, as the types of the agricultural plants of the Leguminous family, have also been the subjects of experiment for several years past, and we hope before long to complete the results for publication.

Besides the experiments of a more purely agricultural scale and character, however, it was thought that the explanation of the alternation of crops would materially be aided by any additional information as to the characteristic qualitative and quantitative functional actions of some of the plants which ordinarily find a place in rotation. With this view, it was sought to ascertain, as in some degree a measure of the activity of the processes of the plants, the amount of water passed through those belonging to different natural orders, and holding different positions in rotation, both as compared one with another, and in reference to the quantitative fixation in the plants of several of their more important constituents, having regard also, as far as was practicable, to the source of these constituents—that is to say, as to whether they were derived from the soil or from the atmosphere.

The experiments, as thus far proceeded with, however, can be considered as little more than initiative, especially so far as the demonstration of those important *agricultural* problems, for the elucidation of which they have mainly been designed, is concerned: were it otherwise, indeed, the pages of this Journal would not be deemed the fittest medium for the publication of results of more purely agricultural interest. The facts already obtained, however, are not without interest to the botanist and the vegetable physiologist; and it is as a contribution to the scanty information already at command, on the subject of the amount of water given off during the growth of plants, that these results are arranged and presented to the reader. It will nevertheless be seen, that they provide some important and interesting indications in reference to the more special object of our investigation, and at the same time afford some useful suggestions for its future conduct.

In deciding upon the method of procedure, the choice seemed to be between such experiments as would yield somewhat rapid, and in some points, perhaps, more direct information, though at the cost of the health and perhaps matured growth of the plant, on the one hand, and a closer imitation of the usual circumstances *of growth* on the other—by which, however, *inferences* rather

than *demonstration* might be elicited. The latter course was chosen, more especially as there are well-conducted experiments of the former kind on record, which it was thought might serve to check or confirm some conclusions which our own results, taken alone, might be held not fully to justify.

It was considered important to provide such conditions for the plants as should enable them to live and mature their seed, if such were the product for which they were usually cultivated—an end not very easily accomplished in the case of plants growing through a period of several months, and requiring an accurate registry of the water passing through them. This was not, indeed, in every case satisfactorily attained, as will be explained further on. But if, from this cause, any otherwise general indications should seem to be opposed by figures, at first sight, discrepant, a little further consideration may perhaps show that, if these are coincident with irregularities of growth and maturation, they may be taken rather as confirmations than as contradictions of any conclusions to which the results of the more naturally developed plants might lead us. We shall, however, submit to the reader a sufficient description both of the methods of experimenting, and of the results, as they were actually obtained, whether numerically or by observation merely—leaving him, therefore, in a position to judge of the value of any suggestions we may offer, whilst the experience thus far attained will, it is expected, enable us to avoid in future some of the irregularities complained of, and the results then supplied will serve amply to confirm or correct any inferences at present hazarded.

The plants selected for experiment were *Wheat* and *Barley*, of the natural order Graminaceæ; with *Beans* and *Peas* as Corn-plants, and *Clover* as a Fodder-plant, from the Leguminosæ—these several plants, moreover, occupying somewhat important and characteristic positions in a course of rotation. A *Root-crop* would also have been taken, but for the great and manifest difficulties of arranging the experiment. These we hope to overcome, however, in the coming season.

The main desiderata in the arrangement of the experiments were—

To provide the plants with soils of some known history and composition or resources, and in quantities sufficient to allow of a natural development of the roots.

To prevent any serious amount of evaporation from the soil other than through the plants themselves.

To have the means of supplying weighed quantities of water to the soils as it was needed.

To determine by the balance the amount of water given off by the plant within any desired period of observation.

To determine the total amount of water passed through the plant during the entire period of its growth; and in relation to this, the amounts of dry produce, and several of its constituents, fixed in the plant.

To determine the source of these fixed constituents, whether soil, manure, or atmosphere.

We are prepared for the objections which may be raised against the means adopted for attaining the end and indications desired, and against the competency of the results, when obtained, to afford *demonstration* on some important points of the inquiry. Yet it is not unadvisedly that some of them, at least, have been risked, and especially in reference to the question of the exact composition and resources of the soils employed, do we not scruple to declare, though in opposition to the known opinions of several esteemed chemical friends, that we are more disposed, for the present at least, to rely upon the comparative indications which a natural and unanalysed but exhausted soil may yield alone, and in admixture with manures of known composition, than upon one of an artificial kind, such as pure sand, for example—or upon the results of analysis at the *commencement* of the experiments. Indeed, in proof of the dangers and uncertainty to which we are exposed in judging of the exact capabilities of a soil by its analysis, and especially of an exhausted one, wherein all the more important constituents are so small in quantity, we need only call attention to the very elaborate examination of this subject in the hands of Professor Magnus, as detailed in his account, 'Uber Versuche betreffend die Erschöpfung des Bodens.'

The knowledge we obtain by synthesis in the method adopted and described further on, with the comparisons which will in time be provided, is, we believe, our safer guide. Specimens of the soil, as originally taken for the experiments, are, however, preserved for analysis at some future time, when the whole subject of the composition and properties of soils can be entered into—and when, also, by the continuous growth of the different plants as proposed, the *balance* of the constituents in the cases of the several experiments will be so far affected as to yield sufficiently wide variations, and therefore trustworthy points of comparison.

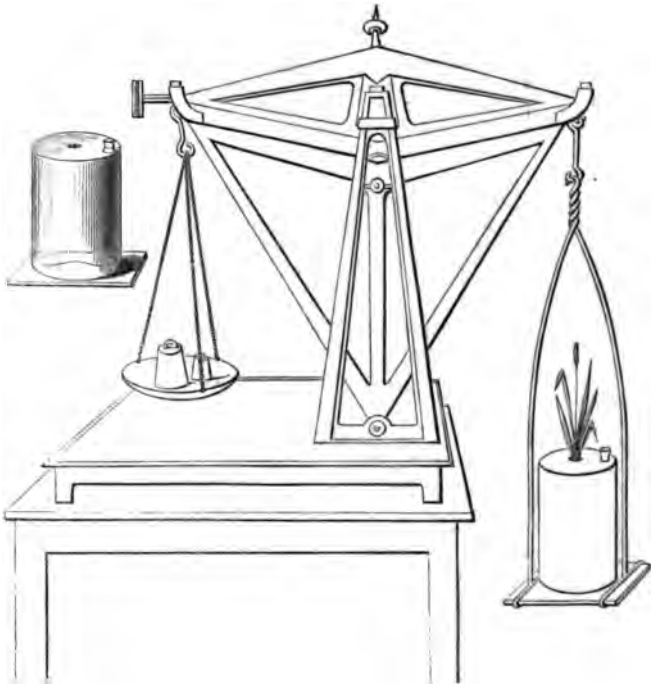
As already stated, the plants selected for experiment were—Wheat, Barley, Beans, Peas, and Clover. Seeds of the first four of these were sown in a box of mould, where they were allowed to reach the height of about 3 inches before being transferred to the experimental pots; but the Clover plant was brought direct from the field. One or more of each description of plant was grown in each of three different conditions of soil,

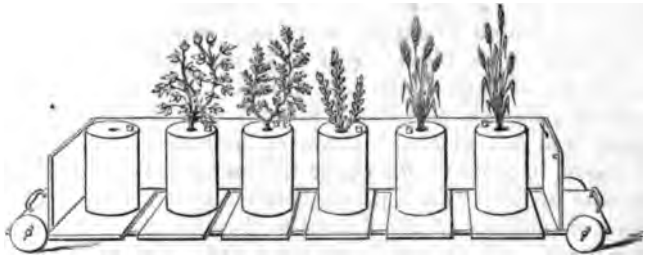
and each set of the five plants with the same description of soil constituted a *Series*. An inspection of the following plan will aid a conception of the arrangement of the experiments as to condition of soil and description of plant:—

Series 1	Soil—from a plot of land from which ten successive corn-crops had been taken without manure (the larger stones being sifted out and the weeds picked)	Wheat, Barley, Beans, Peas, Clover, No plant.
Series 2	Soil—as in Series 1, with mineral manure, containing Sulphate of Potash, Sulphate of Magnesia, Chloride of Sodium, and Superphosphate of Lime	Wheat, Barley, Beans, Peas, Clover.
Series 3	Soil—as in Series 1, with the mineral manure of Series 2, and the Muriate of Ammonia added	Wheat, Barley, Beans, Peas, Clover.

Glass jars, 14 inches in depth and 9 inches in diameter, and which were capable of holding about 42 lbs. of soil, were the vessels employed. Six of these were filled with the soil as described for *Series* 1; five with that of *Series* 2; and five with that of *Series* 3: there being in all, therefore, sixteen separate experimental jars. Into these, excepting the sixth jar of *Series* 1, the plants raised, as described above, were transferred; those from three seeds each of the Wheat and of the Barley being taken, and one plant only of the Beans, Peas, and Clover. A glass plate having a hole in the centre about three-quarters of an inch in diameter for the plants to grow through, and another nearer the side, by which to supply water as it was needed, and which was at other times closed by a cork, was then firmly cemented upon the top of each of the sixteen jars. The sixth jar of *Series* 1, however, though provided with soil and closed with a lid as the rest, was left without a plant, as indicated in the tabulated plan above, in order to determine the amount of evaporation from the centre orifice. Each jar was placed upon a varnished board, for the convenience of attachment to the arm of the balance, and, as thus fitted and mounted, weighed little short of half a hundred-weight. The jars on their stands constituting a Series, were placed upon a truck, by means of which they were sometimes drawn into a green-house for the night, and under the balance when it was desired to weigh them, and on to a grass-plot during the day for free exposure to sun and air; a canvas awning being provided, however, to protect them in case of rain. These arrangements will be clearly understood on inspection of the

annexed drawing, in which is represented a *Series* of the jars with their plants, fixed upon their scale boards, and placed upon their truck.





The balance employed for weighing the plants was constructed for the purposes of these experiments by Mr. Oertling of London, and is calculated to turn with the third of a grain when loaded with from half a hundredweight to a hundredweight in each pan. A drawing of them is also given with a jar and plant as in process of being weighed. The knife-edge of the balance was relieved in the usual way by a support to the beam when not in

actual use; this being removed or applied at pleasure by means of a lever, the arrangement for which is not, however, indicated in the drawing. The whole was, moreover, covered by a frame of glass, provided with a door by which to gain access to the weight-pan, and another for the attachment of the loose arm by which the jar and plant are suspended. A standard counterpoise, consisting of two leaden weights, was kept in the weight-pan, the deviations only above and below this amount being determined by weights—a set of which, from ten thousand grains down to one-tenth of a grain, was provided for this purpose. As will shortly be seen, however, the amounts of water given off by the plants were very large; and after a time it was not deemed necessary in practice to determine the weight within one grain, or frequently even two.

Between the time of planting and the full growth of the plants more than twenty weighings of most of them were taken; and weighed quantities of water were supplied whenever it seemed to be required.

The collected results of the water supplied, or given off by the plants, are exhibited in the following tables:—

In the Table (No. I.), page 10, as well as in those which follow it, the results are arranged in two sections; the upper one bringing more prominently to view the comparisons between the different plants with one and the same condition of soil, and the lower one those of the same description of plant with the varying conditions of soil.

The summary of the total water given off during the growth of the plants, as shown in the third column of this Table, is, of course, chiefly of interest in connection with the coincident accumulation of vegetable substance, and it will therefore be repeated, and further considered, when we come to treat of that part of the subject. Attention may here be called, however, to the evidence afforded by a glance at the figures of this column—whether in the upper or the lower section—at the much greater regularity in Series 1 without manure, and in Series 2 with mineral manure only, than in Series 3 with both mineral and ammoniacal manures. Indeed, from the beginning, the plants of Series 3 were unhealthy, and, as indicated in the tables, only the wheat and the barley survived to the end of the experiment, and these even gave a produce far inferior to the same description of plants under the other conditions, though the ammonia provided by the manure amounted in this case to only about 0·1 per cent. upon the weight of the soil.

It is seen that, in the cases of the healthy plants, there has been an average of about 100,000 grains of water given off by them during their growth, an amount far greater than was anti-

cipated

TABLE I.—SHOWING the TOTAL AMOUNTS of WATER supplied, derived from the SOIL, and given off, during the entire period of the growth of the PLANTS. Quantities given in grains.

Entire Period of 172 days, from March 19 to Sept. 7.

		Total Water supplied.	Total Water obtained from Soil.	Total Water given off.
Unmanured ..	Wheat	79,800	33,727	113,527
	Barley	88,800	31,225	120.025
	Beans	87,800	24,431	112,231
	Peas	81,800	27,282	109,082
	Clover (cut June 28th)	28,500	26,593	55,093
With Mineral Manure	Wheat	85,800	12,206	98,006
	Barley	97,800	30,554	*128,354
	Beans	95,800	22,069	117,869
	Peas	86,000	10,405	96,405
	Clover (cut June 28th)	36,500	17,223	53,723
With Mineral and Ammoniacal Manure	Wheat	57,700	.. ..	55,996
	Barley	74,300	10,824	85,124
	Beans (died)	.. ..	.. ..	.. ..
	Peas (died)	.. ..	.. ..	.. ..
	Clover (cut July 4th)	24,300	.. ..	13,671

Wheat	Unmanured	79,800	33,727	113,527
	Mineral Manure ..	85,800	12,206	98,006
	Min. and Am. Man. ..	57,700	.. ..	55,996
Barley	Unmanured	88,800	31,225	120,025
	Mineral Manure ..	97,800	30,554	128,354
	Min. and Am. Man. ..	74,300	10,824	85,124
Beans	Unmanured	87,800	24,431	112,231
	Mineral Manure ..	95,800	22,069	117,869
	Min. and Am. Man. ..	(died)	.. ..	.. ..
Peas	Unmanured	81,800	27,282	109,082
	Mineral Manure ..	86,000	10,405	96,405
	Min. and Am. Man. ..	(died)	.. ..	.. ..
Clover	Unmanured	28,500	26,593	55,093
	Mineral Manure ..	36,500	17,223	53,723
	Min. and Am. Man. ..	24,300	.. ..	13,671

* The glass lid was broken by the pressure of the plants, and the soil therefore partly exposed.

cipated when the arrangements for the experiments were made; and it will readily be understood that, with such quantities as these, it was seldom necessary to conduct the weighings with the nicety for which we were prepared.

The first and second columns of the Table show the sources of the water given off, from which it is seen that an amount varying from 10,000 to 30,000 grains has been derived from the soil, the remainder having been supplied as the experiment proceeded. It should be remarked, however, that before the commencement of the experiment, 30 fluid ounces, or between 14,000 and 15,000 grains of water, were added to each of the jars of soil, which, by exposure to the air for some time with shelter from the rain, and by the process of sifting, had become somewhat dry. The figures in the Table therefore overstate, by nearly the quantity just mentioned, the amount obtained from the normal soil. Nevertheless it is believed that the wheat and the barley plants suffered to some extent during the latter period of the experiment for want of a freer supply of water, and that to this cause may in part be attributed a defective development of their seeds as compared with those of the beans and peas.

We have not prepared any detailed account of the periodical supply of water, which was regulated, both as to time and quantity, in part by the amount given off by the plants, and partly also by their apparent or supposed requirements. It may be stated, however, that none was added during the first few weeks of the experiments, and that the doses given varied from 250 grains to as much as 1, 2, 3, 4, 6, or even 12 thousand grains as the growth of the plants progressed.

A somewhat more detailed view of the amounts of water given off by the plants may be of interest, and we have accordingly supplied, in Tables II. and III. (pp. 12, 13), statements both of the total and the average daily loss during periods, in the main, as nearly approaching to one month each, as the details of our registry would permit.

The relationship of evaporation to rapidity of growth is, it is true, as yet a problem, but it may nevertheless be assumed as a general fact—and especially between plant and plant of the same description—that the comparative rate of the evaporation of water, or its amount within any given period, to some extent indicates the comparative activity of the processes of the plants; yet, since, with the advance of the season, and increased intensity of heat and light, the surface for evaporation was also constantly increasing, it is difficult to determine whether the increasing loss up to a certain period, as indicated in the tables, is, to any extent, materially due to the *external* influence referred to, *irrespectively* of a corresponding enlarged surface and rapidity of fixation of constituents.

TABLE II.—SHOWING the NUMBER of GRAINS of WATER given off by the Plants during stated divisional Periods of their Growth.

Description of Plant and Manure.		9 Days. From Mar. 19 to Mar. 28.	31 Days. From Mar. 28 to Apr. 28.	27 Days. From April 28 to May 25.	34 Days. From May 25 to June 28.	30 Days. From June 28 to July 28.	14 Days. From July 28 to August 11.	27 Days From Aug. 11 to Sept. 7.
SERIES I.—Unmanured	Wheat	129	1268	4,385	40,030	46,060	15,420	6,235
	Barley	129	1867	12,029	37,480	45,060	17,046	6,414
	Beans	88	1854	4,846	30,110	58,950	12,626	3,657
	Peas	101	1332	2,873	36,715	62,780	5,281	..
	Clover	400	1645	2,948	50,100	..	..	..
SERIES II.—Mineral Manure	Wheat	106	888	3,935	33,800	41,200	9,364	8,713
	Barley	157	2030	11,249	38,280	51,830	14,548	10,260
	Beans	69	1528	4,790	35,440	59,680	11,626	4,706
	Peas	111	1558	4,249	37,060	51,520	1,907	..
	Clover	353	1838	5,008	46,524	..	..	..
					April 28 to June 28.			
SERIES III.—Mineral and Ammoniacal Manure	Wheat	139	866	..	10,300	27,710	15,251	2,030
	Barley	138	853	..	27,270	37,050	14,606	5,207
	Beans	80	1439	1,851	(died)	..	..	..
	Peas	(died)	..	..	..	..	..	..
	Clover	..	..	..	..	..	..	..
No plant		109	633	362	1,374	1,066	300	..

		9 Days.	31 Days.	27 Days.	34 Days.	30 Days.	14 Days.	27 Days.
Wheat	Unmanured ..	129	1268	4,385	40,030	46,060	15,420	6,235
	Mineral Manure	106	888	3,935	33,800	41,200	9,364	8,713
	Min. and Am. Man.	139	866	..	10,300	27,710	15,251	2,030
Barley	Unmanured ..	129	1867	12,029	37,480	45,060	17,046	6,414
	Mineral Manure	157	2030	11,249	38,280	51,830	14,548	10,260
	Min. and Am. Man.	138	853	..	27,170	37,050	14,606	5,207
Beans	Unmanured ..	88	1854	4,846	30,110	58,950	12,626	3,657
	Mineral Manure ..	69	1528	4,790	35,440	59,680	11,626	4,706
	Min. and Am. Man.	80	1439	1,851	(died)	..	..	..
Peas	Unmanured ..	101	1332	2,873	36,715	62,780	5,281 Cut Aug. 11.	..
	Mineral Manure ..	111	1558	4,249	37,060	51,520	1,907 Cut Aug. 4.	..
	Min. and Am. Man.	(died)	..	..	..	..	..	..
Clover	Unmanured ..	400	1645	2,948	50,100	..	..	..
	Mineral Manure	353	1838	5,008	46,524	..	..	..
	Min. and Am. Man.	..	..	..	..	..	..	..

TABLE III.—SHOWING the AVERAGE DAILY LOSS of WATER (in Grains) by the PLANTS, within several stated divisional Periods of their Growth.

Description of Plant and Manure.		9 Days. From Mar. 19 to Mar. 28.	31 Days. From Mar. 28 to Apr. 28.	27 Days. From April 28 to May 25.	34 Days. From May 25 to June 28.	30 Days. From June 28 to July 28.	14 Days. From July 28 to Aug. 11.	27 Days. From Aug. 11 to Sept. 7.
SERIES I.—Unmanured	Wheat	14·3	40·9	162·4	1177·4	1535·3	1101·4	230·9
	Barley	14·3	60·2	445·5	1102·3	1502·0	1217·6	237·5
	Beans	9·7	59·8	179·5	885·6	1965·0	901·8	135·4
	Peas	11·2	42·9	106·4	1079·8	2092·7	377·2	..
	Clover	44·4	53·0	109·2	1473·5	..	..	..
SERIES II.—Mineral Manure ..	Wheat	11·8	28·6	145·7	994·1	1373·3	668·8	322·7
	Barley	17·4	65·5	416·6	1125·9	1727·7	1039·1	380·0
	Beans	7·6	49·3	177·4	1042·3	1989·3	830·4	175·4
	Peas	12·3	50·3	157·0	1090·0	1717·3	136·2	..
	Clover	39·2	59·3	185·5	1368·3	..	..	..
SERIES III.—Mineral and Ammoniacal Manure ..	Wheat	15·4	27·9	April 28 to May 12. 373·1	May 12 to June 28. 108·0	923·7	1068·0	75·2
	Barley	15·3	27·5	April 28 to May 9. 136·4	May 9 to June 28. 515·4	1235·0	1043·3	192·8
	Beans	8·8	46·4	April 28 to May 9. 168·3	..	..	..	..
	Peas	..	..	..	..	..	..	..
	Clover	..	..	..	..	..	..	..
No Plant		12·1	20·4	13·4	40·4	35·5	21·4	

		9 Days.	31 Days.	27 Days.	34 Days.	30 Days.	14 Days.	27 Days.
Wheat	Unmanured ..	14·3	40·9	162·4	1177·4	1535·3	1101·4	230·9
	Mineral Manure	11·8	28·6	145·7	994·1	1373·3	668·8	322·7
	Min. and Am. Man.	15·4	27·9	14 Days. 373·1	47 Days. 108·0	923·7	1068·0	75·2
Barley	Unmanured ..	14·3	60·2	445·5	1102·3	1502·0	1217·6	237·5
	Mineral Manure	17·4	65·5	416·6	1125·9	1727·7	1039·1	380·0
	Min. and Am. Man.	15·3	27·5	11 Days. 136·4	50 Days. 515·4	1235·0	1043·3	192·8
Beans	Unmanured ..	9·7	59·8	179·5	885·6	1965·0	901·8	135·4
	Mineral Manure	7·6	49·3	177·4	1042·3	1989·3	830·4	175·4
	Min. and Am. Man.	8·8	46·4	11 Days. 168·3	..	..	..	..
Peas	Unmanured ..	11·2	42·9	106·4	1079·8	2092·7	377·2	..
	Mineral Manure	12·3	50·3	157·0	1090·0	1717·3	136·2	..
	Min. and Am. Man.	..	..	..	..	..	..	..
Clover	Unmanured ..	44·4	53·0	109·2	1473·5	..	..	..
	Mineral Manure	39·2	59·3	185·5	1368·3	..	..	..
	Min. and Am. Man.	..	..	..	..	..	..	..

constituents. So far, of course, as the process is one of *simple evaporation*, will an increase of temperature determine a greater loss of water; still the question arises whether—supposing there be no actual deficiency of the necessary and available constituents—this increased passage of water through the plants, carrying with it in its course many important materials of growth from the soil, and probably also influencing the changes in the leaves of these, as well as of those derived from the atmosphere, will not be accompanied with an equivalently increased growth and development of the substance of the plant. Upon this point some light may be thrown by an examination of the circumstances attending the development of "Roots," the more active growth of which is generally coincident with a declining and not an increasing temperature, as in the case of the seeding crops now under trial.

Until, however, the relationship of the quantity of water given off to the amount of dry substance or its constituents fixed, under varied and known circumstances, be experimentally determined, any detailed consideration of the indications of the thermometer in connection with results of so initiative a kind would be unavailing, though a more or less complete registry was kept of the temperature during the period of the growth of the plants, and this point will not be neglected in our future progress.

As might have been anticipated, it is seen by the Tables, that though, as the season advanced in temperature and the mass and surface of the plants increased, the amount of water daily given off was also greater up to a given time, yet towards the end of the experiment it rapidly and considerably diminished. It is probable that, from the time of this apparent decline in the rate of passage of water through the plant, the processes of acquirement of material were less active, those of the ripening and elaboration of its contents having commenced, and that the time of most active circulation, as indicated by the daily rate of water evaporated, was also that of the greatest *accumulation*. Some experiments which we conducted a few seasons ago, with the view of determining whether there was, in the formation and ripening of the cereal grains, any diminution in the amount of nitrogen previously stored in the plant, seemed, indeed, to show, that though there was no appreciable change in the amount of the nitrogenous compounds upon a given area of land after the time of flowering, yet the amount of *non*-nitrogenous vegetable substance accumulated after this time had been very great; it is not, however, necessary to conclude that the rapid accumulation of carbon from the atmosphere at this period, though coincident perhaps with an apparently less succulent condition of the plant, was in reality *attained* with any less degree of activity of the fluids within it,

or of watery exhalation from it, than during the earlier stages of its growth. Upon this point some information will probably be afforded by our results as we proceed.

The daily rate of evaporation in the cases of the two more healthy clover plants—those, namely, of Series 1 and 2—is seen to be in the main higher, up to the time of their being cut, than in those of the other plants; in explanation of which, it must be remembered that the clover experimented upon, being the produce of seed sown in the previous season, these plants were, at the commencement, more advanced than those with which they here stand in comparison.

The total evaporation from the jar without a plant is seen to be 3844 grains during the entire period of the experiment. This total loss from the hole in the glass lid is certainly considerable, but it amounts on an average to little more than 3 per cent. of the entire quantity given off from the jars containing the plants, and it seems unsafe on several grounds to attempt to correct the indications of the latter by the deduction of the amount of loss from the no-plant jar. Thus, the loss from the centre-hole of the no-plant jar might be supposed to exceed that from the rest, since in these the orifice was nearly closed by the stems of the plants; but, on the other hand, the much less active circulation of air through the unplanted jar would tend to an opposite result, as also would the fact, that in the absence of a fresh supply of water in this case, the surface of the soil would, after a time, become somewhat dry. That this was the case would appear from the figures in the Table, which show that though the rate of loss from the no-plant jar increased for a length of time as the season advanced, yet afterwards it to some extent diminished. It may be remarked, however, that there was frequently in this case, as well as in the others, a condensation of water on the under surface of the lid. Upon the whole, then, we are inclined to decide, that the indications of this experiment should serve rather to prevent any too nice application of the numerical results obtained in relation to the plants, than as providing any available means of correcting them.

Let us now turn our attention to the amount and composition of the produce obtained from the experimental jars. The wheat plants in all three of the jars appearing sickly from the time of transplanting, were cut down twelve days afterwards, viz., on March 31st, in the hope that they would then grow up more vigorously. These cuttings, when dried at 212°, in neither case weighed one grain, but they were saved, and their quantities are taken into account with the rest of the produce. Stems were also cut from the wheat grown by the unmanured and the mineral

manured soil, as well as from all of the barley jars, on May 26th; the holes in the glass covers having become in these cases quite choked up. These cuttings were much more considerable in quantity than the former, and of course also considered as a part of the experimental product.

The several clover plants were respectively cut when in full flower. The pea with mineral manure was cut on August 4th, and that in the unmanured soil on August 11th. All the other plants, viz., wheat, barley, and the beans, were harvested on September 7th.

The corn of the peas and beans was well developed and tolerably ripened: that of the wheat and the barley was by no means so much so, especially that of the wheat. This was supposed partly to arise from a want of water, the plants having an appearance of drying up rather than healthy ripening. It is seen, indeed, by reference to Table I., at page 10, that the amounts of water derived from the soil were greater in the cases of one of the wheat jars and two of the barley jars than in the others, though the exhaustion, in this respect, of the beans, one of the peas, and one of the clovers, was not much less. It had been remarked, however, from the commencement, that the apparent demand for supplied water was much greater in proportion to that given off in the cases of the graminaceous plants than in the several leguminous ones; but it seems generally to have been found by experimenters, that the cereals were much more difficult to bring to maturity under the somewhat artificial circumstances usually provided in experiments of this kind, than any other plants.

The irregularities of cuttings and want of uniformity in the final maturation of the produce will be guarded against as far as possible in our future experiments. To these indeed may probably be chiefly attributed any want of definiteness or consistency in the results about to be considered; and it was on account of them deemed unnecessary to take the *fresh* weights of the produce of the jars.

The plants cut level with the surface of the perforated lids, shortly after being taken from the jars were dried in a stove at about 140°, and then carefully stored for future examination.

Recurring to the subject for the purpose of this paper, the corn plants were carefully dissected—the seeds from the straw, chaff, &c. Each of them was then exactly halved. The one portion of corn, and one each of straw, chaff, &c. (the latter being mixed together), were fully dried at 212°—the weight taken and then burnt to ash, and the other specimens, the corn separately from the straw, chaff, &c., being reserved for the determination of their nitrogen. The cuttings were also halved and treated in

like manner, those taken at different periods from the same plant having been mixed.

In Tables IV., V., and VI., are given the results of the dryings and burnings of the produced plants.

TABLE IV.—QUANTITIES (in grains, tenths, &c.) of Dry Matter fixed in the several parts of the Plants, and in the Total Produce of the Jars, &c.

Description of Plants and Manure.		In Corn.	In Straw and Chaff.	In Cuttings	In Total Produce.	Proportion of Corn to 100 of Straw, &c.
Wheat	Unmanured	148·5	302·8	7·6	458·9	47·84
	Mineral Manure	111·2	321·9	7·6	440·7	33·74
	Mineral and Ammon. Manure	65·4	206·2	0·3	271·9	31·67
Barley	Unmanured	188·7	253·74	23·1	465·54	68·16
	Mineral Manure	179·0	297·0	24·6	500·6	55·66
	Mineral and Ammon. Manure	112·8	170·6	29·8	313·2	56·34
Beans	Unmanured	282·6	254·9	..	537·5	110·86
	Mineral Manure	299·0	238·8	..	537·8	125·20
Peas	Unmanured	214·7	206·3	..	421·0	104·07
	Mineral Manure	213·8	243·6	..	457·4	87·76
Clover	Unmanured	..	..	..	204·7	..
	Mineral Manure	..	..	..	234·8	..
	Mineral and Ammon. Manure	..	..	..	92·6	..

TABLE V.—QUANTITIES (in grains, tenths, &c.) of Mineral Matter fixed in the several parts of the Plants, and in the Total Produce of the Jars, &c.

Description of Plants and Manure.		In Corn.	In Straw and Chaff.	In Cuttings.	In Total Produce.
Wheat	Unmanured	4·22	30·62	1·65	36·49
	Mineral Manure	3·06	40·44	1·44	45·48
	Mineral and Ammon. Manure ..	2·16	29·74	0·048	31·948
Barley	Unmanured	6·2	36·38	3·34	45·92
	Mineral Manure	6·8	39·22	4·6	50·62
	Mineral and Ammon. Manure ..	4·72	24·06	4·4	33·18
Beans	Unmanured	9·02	40·0	..	49·02
	Mineral Manure	10·6	36·16	..	46·76
Peas	Unmanured	6·76	36·4	..	43·16
	Mineral Manure	8·24	55·98	..	64·22
Clover	Unmanured	..	..	..	29·24
	Mineral Manure	..	..	..	35·44
	Mineral and Ammon. Manure ..	..	..	..	13·10

TABLE VI.—Percentages of Ash in Dry Matter.

Description of Plants and Manure.		In Corn.	In Straw and Chaff.	In Cuttings.	In Plant (Clover).
Wheat	Unmanured	2·84	10·11	21·71	..
	Mineral Manure	2·75	12·56	18·95	..
	Mineral and Ammon. Manure	3·30	14·42	16·0	..
Barley	Unmanured	3·28	14·34	14·46	..
	Mineral Manure	3·80	13·20	18·70	..
	Mineral and Ammon. Manure	4·18	14·1	14·1	..
Beans	Unmanured	3·19	15·69	..	..
	Mineral Manure	3·55	15·14	..	..
Peas	Unmanured	3·15	17·64	..	..
	Mineral Manure	3·85	23·0	..	..
Clover	Unmanured	..	..	..	14·28
	Mineral Manure	..	..	..	15·11
	Mineral and Ammon. Manure	..	..	..	14·15

In Table IV. the *dry matter* in the several *parts* of the specimens is given, the quantities being calculated upon the entire produce of the jars. Excluding the clover-plants, which do not compare fairly with the rest, and those also having the ammoniacal manure, which were evidently injured by it, we see at least some general uniformity in the amount of dry matter produced; the beans, however, which were of all the plants the most healthy, yielding not only an amount almost identical with the unmanured and the mineral-manured soils, but higher than any of the rest. And if we refer to the last column of the Table, we see that in their cases especially, but also notably in those of the peas, the seed (which in both is so highly nitrogenous) shows a *much* higher proportion to the entire produce than in the cereals.

These *actual quantities* of dry matters produced, though indicating, perhaps, to some extent the healthy development of the several plants under the conditions provided for them, will be more conveniently studied in their relationship to the amount of water given off, when calculated to a uniform standard, as in the Table which will shortly follow.

The figures of Table V., indicating the actual amounts of *mineral matter* fixed in the plants, are also of little independent interest. Those of Table VI. show the percentage of *mineral matter* in the gross dry substance in the several plants and parts of plants, and indicate it to be in every instance higher than is usual; though less so in the Leguminous seeds than in the

cereals, and more in the wheat than in the barley. The proportion is seen, moreover, to vary in the same description of plant with the different conditions of soil, it being generally higher where mineral manure was employed than with no manure. This general excess of mineral matter may be taken as being connected, to a great extent, with the defective state of ripening of the plants, and between plant and plant of the same description the amount of it may indicate their relative qualities in this respect.

TABLE VII.—TABLE of Actual Experimental Results.

Description of Plant and Manure.		Number of Grains of Water given off.	Number of Grains fixed in the Plant of—		
			Dry Matter.		Mineral Matter (Ash).
			Inclusive of Ash.	Organic only.	
Unmanured	Wheat	113,527	458·9	422·41	36·49
	Barley	120,025	465·54	419·62	45·92
	Beans	112,231	537·50	488·48	49·02
	Peas	109,082	421·00	377·84	43·16
	Clover	55,093	204·70	175·46	29·24
Mineral Manure ..	Wheat	98,006	440·7	395·76	44·94
	Barley	128,354	500·60	449·98	50·62
	Beans	117,869	537·80	491·04	46·76
	Peas	96,405	457·40	393·18	64·22
	Clover	53,723	234·80	199·32	35·48
Mineral and Ammoniacal Manure ..	Wheat	55,996	271·90	239·952	31·948
	Barley	85,124	313·20	280·02	33·18
	Clover	13,671	92·60	79·50	13·10
Wheat ..	Unmanured	113,527	458·9	422·41	36·49
	Mineral Manure	98,006	440·7	395·76	44·94
	Min. and Ammon. Manure ..	55,996	271·90	239·952	31·948
Barley ..	Unmanured	120,025	45·564	419·62	45·92
	Mineral Manure	128,354	500·60	449·98	50·62
	Min. and Ammon. Manure ..	85,124	313·20	280·02	33·18
Beans ..	Unmanured	112,231	537·50	488·48	49·02
	Mineral Manure	117,869	537·80	491·04	46·76
Peas ..	Unmanured	109,082	421·00	377·84	43·16
	Mineral Manure	96,405	457·40	393·18	64·22
Clover ..	Unmanured	55,093	204·70	175·46	29·24
	Mineral Manure	53,723	234·80	199·32	35·48
	Min. and Ammon. Manure ..	13,671	92·60	79·50	13·10

In Table VII. (p. 19) the total amounts of water given off during the growth of the plants, and the total amounts of dry matter, both inclusive and exclusive of ash, and of the ash itself, are given side by side. The relationship of the water given off to the matter fixed in the plant is, however, more clearly indicated in Tables VIII. and IX.

TABLE VIII.—SHOWING the Quantities of Substances fixed to a Standard Amount of Water given off.

Description of Plant and Manure.		Number of Grains fixed in the Plant for 100,000 Grains of Water given off, of—		
		Dry Matter.		Mineral Matter (Ash).
		Inclusive of Ash.	Organic only.	
Unmanured	Wheat	404·2	372·0	32·14
	Barley	387·8	349·6	38·26
	Beans	478·9	435·2	43·67
	Peas	385·9	346·4	39·57
	Clover	371·5	318·5	53·07
Mineral Manure	Wheat	449·7	403·8	45·85
	Barley	390·0	350·6	39·44
	Beans	456·3	416·6	39·67
	Peas	474·4	407·8	66·61
	Clover	437·0	371·0	66·04
Mineral and Ammoniacal Manure	Wheat	485·6	428·5	57·05
	Barley	367·9	328·9	38·98
	Clover	677·3	581·5	95·82

Wheat	Unmanured	404·2	372·0	32·14
	Mineral Manure	449·7	403·8	45·85
	Mineral and Ammoniacal Manure	485·6	428·5	57·05
Barley	Unmanured	387·8	349·6	38·26
	Mineral Manure	390·0	350·6	39·44
	Mineral and Ammoniacal Manure	367·9	328·9	38·98
Beans	Unmanured	478·9	435·2	43·67
	Mineral Manure	456·3	416·6	39·67
Peas	Unmanured	385·9	346·4	39·57
	Mineral Manure	474·4	407·8	66·61
Clover	Unmanured	371·5	318·5	53·07
	Mineral Manure	437·0	371·0	66·04
	Mineral and Ammoniacal Manure	677·3	581·5	95·82

TABLE IX.—SHOWING the Quantities of Water given off to a Standard Amount of Substances fixed.

Description of Plant and Manure.		Number of Grains of Water given off for One Grain fixed in the Plant, of—		
		Dry Matter.		Mineral Matter (Ash).
		Inclusive of Ash.	Organic only.	
Unmanured	Wheat	247·4	268·8	3111·2
	Barley	257·8	286·0	2613·8
	Beans	208·8	229·7	2289·5
	Peas	259·1	288·7	2527·3
	Clover	269·1	314·0	1884·2
Mineral Manure	Wheat	222·4	247·6	2180·8
	Barley	256·4	285·2	2535·6
	Beans	219·2	240·0	2520·7
	Peas	210·8	245·2	1501·2
	Clover	228·8	269·5	1514·2
Mineral and Ammoniacal Manure	Wheat	205·9	233·4	1752·7
	Barley	271·8	304·0	2565·5
	Clover	147·6	172·0	1043·6

Wheat ..	Unmanured	247·4	268·8	3111·2
	Mineral Manure	222·4	247·6	2180·8
	Mineral and Ammoniacal Manure ..	205·9	233·4	1752·7
Barley ..	Unmanured	257·8	286·0	2613·8
	Mineral Manure	256·4	285·2	2535·6
	Mineral and Ammoniacal Manure ..	271·8	304·0	2565·5
Beans ..	Unmanured	208·8	229·7	2289·5
	Mineral Manure	219·2	240·0	2520·7
Peas ..	Unmanured	259·1	288·7	2527·3
	Mineral Manure	210·8	245·2	1501·2
Clover ..	Unmanured	269·1	314·0	1884·2
	Mineral Manure	228·8	269·5	1514·2
	Mineral and Ammoniacal Manure ..	147·6	172·0	1043·6

In Table VIII. there are shown the amounts of gross dry substance, of dry organic matter, and of mineral matter fixed, for every 100,000 grains of water carried off from the soil by the plants, and in Table IX. the amount of water given off for the fixation of one grain of each of these is indicated.

The indications of these Tables are certainly not without the appearance of discrepancy; yet when we remember the circum-

stances of irregularity of growth already fully detailed, and also the greatly varying products, of which the substance of the plants is in several cases made up, the *general* uniformity of the figures is sufficiently striking, and calculated to lead to the expectation of much more definite results in future, and more carefully conducted experiments.

Referring first to Table VIII., and taking the upper section of it, we see that the amounts of dry matter produced to 100,000 grains of water given off by the plant, range in the case of the wheat, the barley, the pea, and the clover, in the unmanured soil, between 371 and 404 grains; or, excluding the clover, between the latter number and 386 grains, an approximation sufficiently indicating some definite relationship between the passage of water through the plant and the fixation in it of some of its constituents. The *bean* in this series seems to be an exception, the amount of dry substance produced in this case being about 479 grains, or nearly one-fourth more than the average of the other unmanured plants. When we remember, however, the much larger amount of *nitrogenous* compounds which this product would contain than any of the other specimens, we see that, with this variation in the amount of vegetable growth to a given quantity of water evaporated, there is, at least, coincident variation in the composition of the product itself; and the particular facts would lead to the suspicion, that the water evaporated had a more definite quantitative relationship to the fixation of the *non*-nitrogenous than to that of the *nitrogenous* constituents of the plants.

Looking at the results of the 2nd Series (with mineral manure), we see a generally higher amount of dry substance produced for a given circulation of water than in Series 1; and also, the barley excepted, a much greater uniformity than in the former Series. The cause of this discrepancy in the barley may perhaps be explained by the fact already mentioned, that the lid of the jar in which it grew had been broken during a considerable period of the experiment; and though the pieces were cemented together, yet it is more than probable that water was lost from the soil by evaporation through the crack, in which case the amount of product would necessarily appear low.

In the case of this Series, too, it is seen that the product of beans is exceeded by the peas, and nearly reached even by the wheat. On the view referred to above, therefore, it would be necessary to suppose that, provided the results are to be relied upon, the composition of the several products as regards nitrogen would be more nearly equal in the case of this Series than in the former one, and also that the percentage of it was higher in the

specimens of the second Series than in those of the first—a result which would have to be attributed to the more or less direct influence of the manure.

The plants of *Series* 3, having an ammoniacal manure, were so manifestly unhealthy that the results afforded in relation to them must not be allowed much weight, and indeed they appear to be little worthy of confidence.

In the lower section of Table VIII. the comparison is made between the individuals of the same description of plant under different conditions of soil. A considerable difference is here shown to be coincident with the variations of manuring condition, and, setting aside the clover, more especially in the cases of the wheat and the peas. The composition of these when determined may, to a great extent, elucidate the fact; indeed, the varying proportion of seed to straw in the several cases indicates a probable difference in this respect; and analogy would also lead us to believe that, with the varying observed degree of ripeness and the experimentally ascertained varying amounts of ash, the percentage of nitrogen in the several specimens of the same kind of plant would also vary very greatly. In support of this opinion we may state, that analyses already made of some of the products show that some of the cereals contained nearly twice the ordinary amount of nitrogen. The coincidences in this section are most striking in reference to the beans, and these, as has been already stated, were the most healthy and matured plants obtained from the experimental jars. The three barley plants, it is true, show a considerable uniformity, but, as has already been explained, the figures given for the mineral manure plant are probably somewhat in error.

Notwithstanding these discrepancies, as yet not fully and satisfactorily explained, we cannot but recognise in the results thus far obtained a very encouraging significance; and, indeed, it seems to us more than probable, that future experiments may fix a definite relationship between the amount of water given off and that of the *non*-nitrogenous proximates fixed in the plant, and this even probably to a great extent irrespectively of their exact composition, provided their source were mainly in each case the *atmosphere*, as in the instances of the seeding plants now under consideration, and accumulating, as they are known to do, their chief supplies during the period of the most powerful influence of heat and light upon the plants.

In Table IX. the amounts of water passing through the plant for each grain of substance fixed are given—the indications being the inverse of those we have just been considering; and the differences are of course dependent on the same circumstances as those already alluded to.

It is a striking fact, that (excepting a single clover plant, which was always unhealthy) there is in every case more than 200 grains of water passed through the plant for one grain of material accumulated.

Referring to the column of water evaporated to mineral matter fixed, we see the amount of the former to be, on an average, 2000 times that of the latter. Whatever other explanation, therefore, we may receive as to the conditions of assumption by the plant of some mineral substances occurring in it, in insoluble combinations, we have here evidence sufficient to show that few of the substances required by plants, and which are generally assumed to be insoluble, are incapable of being taken up by them in an adequate quantity in rain water.

It was our hope to have given in this paper the results of the determinations of nitrogen, in the various specimens grown in the pots, with the view of showing what relation subsisted between the amount of nitrogenous proximates fixed in the plant, and that of the water passed through it. Unfortunately, however, the laboratory work in connection with this branch of the inquiry is as yet not so far advanced as to justify the discussion of the numerical results on this occasion, nor will our allotted time allow us to do so. We may, however, state that, as far as our results have gone, it would appear that, whilst for a given quantity of water evaporated the amount of *non*-nitrogenous substances fixed in the plant is within somewhat narrow limits identical, in the specimens now under experiment of the two natural orders of plants, that of the *nitrogenous* proximates fixed is, on the other hand, about *twice* as great in the Leguminosæ as in the Graminaceæ. This is indeed a significant fact, as bearing upon the distinctive functional characters of the various plants which enter into rotation. It is, moreover, perfectly consistent with the results of our experiments in the field with wheat and beans respectively, which show that, under the same circumstances of growth, as to manure, &c., and in the same season, the acreage yield of nitrogen is twice or thrice as great in beans as in wheat.

It cannot be supposed, however, that with the larger amount of nitrogen harvested in the Leguminous crop the soil would be proportionally exhausted of it, for common practice sufficiently teaches that, other things being equal, a larger produce of wheat would be obtained after a bean than after a wheat crop, notwithstanding its known dependence on the supply of nitrogen in the soil.

It may be supposed, indeed, that here we have evidence of a superior power in the Leguminous as compared with the Graminaceous plants, of obtaining their nitrogen from the atmosphere

rather than from the soil. However this may be, many experiments of our own have convinced us that, especially in the growth of the Graminaceous grains, there is never an increased acreage yield of nitrogen in any degree approaching that supplied by manure; and, independently of results of a more direct and practical kind, it has been observed by several experimenters, that during the growth of plants there is a constant evolution of nitrogen from their leaves.

Thus De Saussure, in his 'Recherches Chimiques sur la Végétation,' pp. 40-43, gives the results of experiments on this subject, and he comes to the conclusion that the amount of nitrogen given off bears a direct relation to that of oxygen assimilated by the plant from the absorbed carbonic acid. His experiments, moreover, were made with the *Vetch*, which, as will be remembered, is a member of the Leguminous family of plants, in which, as compared with the Graminaceous family, we would suppose the evolution of nitrogen to be less considerable.

Daubeny, again, in his 'Memoir on the Action of Light upon Plants, and of Plants upon the Atmosphere,' in the 'Philosophical Transactions for 1836,' Part I., arrives at a somewhat similar result; whilst more recently Draper, in his 'Chemistry of Plants,' pp. 184, 185, and context, ascertained in several experiments the amount of nitrogen given off during the growth of plants, and seeks to establish the following conclusions: that "when the leaves of plants under the influence of light decompose carbonic acid, they assimilate all the carbon, and a certain proportion of oxygen disappears; at the same time they emit a volume of nitrogen *equal to that of the oxygen consumed.** This disappearance of oxygen and appearance of nitrogen are thus connected with each other: they are equivalent phenomena. The emission of nitrogen is thus shown not to be a mere accidental result, but to be profoundly connected with the whole physiological action. . . . . At this stage of the inquiry a remarkable analogy appears between the function of digestion in animals and the same functions in plants. Liebig has shown how, from the transformation of the stomach itself, food becomes acted upon, and is turned into chyme; an obscure species of fermentation, brought about by the action of nitrogenized bodies. So in like manner, in plants, the decay of a nitrogenized body is intimately connected with the assimilation of carbon; for, as I have stated, the process here under discussion is a true digestive and not a respiratory process. And as there are facts which seem to show that the primary action of the light is not upon the carbonic acid, but upon the nitrogenized ferment, the decomposition of the gas

* The italics are those of the author.

ensuing as a secondary result, *is it not probable that* CHLOROPHYL *is the body which in vegetables answers to the* CHYLE *of animals?* The oxygen which disappears during the decomposition of carbonic acid, disappears to bring about the eremacausis of the nitrogenized body. And have not the gum, the starch, the lignin, and other carbonaceous constituents of plants, all originally existed in and passed through the green stage?"

Mulder, again, from purely chemical considerations, and, like the observers alluded to above, altogether independently of the important practical application of the phenomena to which we wish to direct attention, admits the constant evolution of nitrogen during the growth of plants, and that the source of this nitrogen must obviously be the compounds containing it already existing in the plants; but he maintains, with more or less apparent reason, that the relation of nitrogen given off to that of oxygen assimilated from the absorbed carbonic acid must depend materially upon the composition of the compounds to be formed. Thus, referring to Draper's experiments, he says (see his 'Chemistry of Vegetable and Animal Physiology,' Part IV., p. 778), "But this simplicity of relation is in my opinion accidental. The carbonic acid is employed for the production of various organic bodies, which cannot possibly be the same in *all* plants. Consequently, the quantity of oxygen given off cannot be a constant one. This variety of product also renders it impossible that a constant amount of nitrogenous substance should be required for the decomposition of the carbonic acid."

It may be taken, then, as a well-ascertained fact, that the evolution of nitrogen is a constant and coincident attendant on the growth and accumulation of a plant; whilst it would seem that both the results of practice and the reasonings of the chemist would lead us to suppose that this loss is greater in some cases than in others.

Let it once be admitted in agricultural science that there is a definite expenditure or consumption of the nitrogenous bodies derived through the roots connected with the fixation and elaboration of certain constituents of plants, and that this is greater or less according to the sources or the exact composition or state of elaboration of the products, and an important step will be gained towards a clearer conception of the principles involved in the alternation, in a course of cropping, of plants of varying products and habits of growth. In one of our papers *On Agricultural Chemistry* in the 'Journal of the Royal Agricultural Society' (Part I., 1847), we have ventured an opinion as to the probable amount of nitrogen required in the manure of wheat to yield a given amount of it in the increased produce. Since that *time we* have accumulated much additional evidence on this

point, which will enable us to modify or confirm the estimate already hazarded, but which it is not the object or the province of this paper to discuss: the results yet to be obtained, however, in continuation of the inquiry constituting the subject of this report, will, it is anticipated, furnish further data bearing upon this important question.

Before concluding these observations, it seems fitting to call attention to some incidental, yet important indications of these and other of our experiments. Granting, as the conjoint results of the field and of the experimental plants here under discussion would show, that, under equal circumstances of growth, and coincidently with the passage into the plant of the same amount of aqueous fluid from the soil, the Leguminous plants will yield a produce varying but little in gross amount from that of the Graminaceæ, but containing a much higher percentage, and, consequently, total quantity of nitrogen, it would, on the view that the analysis of a crop should indicate the manure required for its growth, at once be decided that, of their *organic* constituents, the Leguminous plants should be liberally supplied with *nitrogen*, and the Graminaceæ rather with *carbon*. But is this consistent with common usage or the dictates of experiment? The low nitrogenized and highly carbonaceous Graminaceous crop requires for its luxuriant growth a large supply of nitrogen by manure; but with this it seems practically independent of *supplied carbon*, whilst the highly nitrogenized Leguminous plants are, other things being equal, by no means strikingly benefited by nitrogenous manures. We had, indeed, at one time supposed that clover was greatly dependent on an artificial provision of nitrogen, but this view does not appear to be favoured by further investigation; whilst with it, as well as with those Leguminous plants valued in agriculture for their seeds, a mineral, and especially an alkaline manure, seems to be more prominently indicated.

Again, judging from the composition of the ash of the turnip, which shows both in the leaf and in the bulb a proportion of alkalies to phosphoric acid of 4 or 5 to 1, we should be led to decide that the former, rather than the latter, were usually and specially the more appropriate manure for the turnip. Common practice has, however, definitely determined in favour of phosphoric acid rather than on the alkalies.

Indeed, the whole tendency of agricultural investigation seems to show the fallacy of alone relying upon the knowledge of the composition of a crop, as directing to the constituents probably more specially required to be provided for it by manures, and rather that the elucidation of agricultural principles must be looked for from a due consideration of vegetable physiology as

well as chemistry—of the special functional peculiarities and resources of different plants, as well as their actual percentage composition.

We are convinced, indeed, that however important and useful miscellaneous agricultural analyses may be, the interest and progress of agriculture would be more surely and permanently served, if its great patron Societies were to permit to their scientific officers a wider range of discretion, and more liberal means for the selection and carrying out of definite questions of research. Results of this kind promise, it is true, but little prospect of immediate and direct practical application, but by their aid the uncertain dictates, whether of common experience, theory, or speculation, may, ere long, be replaced by the unerring guidance of principles; and then alone can it reasonably be anticipated that miscellaneous and departmental analyses may find their true interpretation, and acquire a due and practical value.

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AND CHARING CROSS.

REPORT

UPON SOME EXPERIMENTS UNDERTAKEN AT THE SUGGESTION OF PROFESSOR LINDLEY,

TO ASCERTAIN THE

COMPARATIVE EVAPORATING PROPERTIES

OF

EVERGREEN AND DECIDUOUS TREES.

BY J. B. LAWES, ESQ.,
OF ROTHAMSTED.

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EVAPORATION OF EVERGREEN AND DECIDUOUS TREES.

In the month of December, 1849, I selected from a nursery garden three plants each, of the twelve kinds named below; they were fine healthy plants, of a size well adapted for transplanting; and although the three plants of a similar description resembled each other as nearly as it was possible to determine by the eye, the nature of their differences prevented any close agreement between plants of different descriptions. For instance, the Ash, Larch, Oak, and Sycamore, had each one stem of small branches, while the two Berberries, the Laurels, and the Yew, were bushy shrubs. One plant of each sort was planted in a garden, another was reserved for the experiments to be recorded, and a third was weighed, after having the earth washed carefully from the root. The following Table will give some idea of the comparative size of the plants under experiment:—

	Weight of Plant.		Weight of Green Leaves.	
	In ozs. and grs.		In ozs. and grs.	
Spruce Fir	15	160		
Portugal Laurel	18	..	3	350
Evergreen Berberry ..	3	160	1	132
Yew	22	330		
Holly	16	10	1	316
Common Laurel	24	260	9	121
Ilex	4	280	0	434
Larch	4	170		
Oak	2	370		
Deciduous Berberry ..	7	240		
Ash	4	40		
Sycamore	2	24		

Zinc pots, about 20 inches deep and 36 inches in circumference, were filled with good garden mould, mixed with loam, and a tree was planted in each on the 22nd of December: they weighed about 42 lbs. each; on the surface of the pot a zinc plate was fixed, having a hole to admit the stem; these plates did not fit very close, and a certain amount of the water evaporated is due to this cause. Towards the end of April a piece of oilskin was placed over the zinc plate, being fastened round the stem of the tree by India rubber string, and also around the pot below the opening with an elastic band, which effectually prevented all

escape of water except through the trees. The plants were placed in an open shed, protected from the rain, and were supplied with water from time to time as they seemed to require it; the weights were taken by means of the apparatus described in the Journal of the Horticultural Society, of January 1850. Upon referring to Table I. it will be seen that a considerable falling off in the water evaporated is apparent at the period when the oil-skin was put over the openings and the air perfectly excluded. Part of the pots were so covered on April 14th, and the remainder on April 24th; it appears to me probable that the reduction in the water evaporated is not entirely due to the water being prevented from escaping through the hole in the lid, but that it is partly due to an injurious effect upon the plants themselves, some of them having evidently suffered.

With the exception of the Ilex, which declined from the commencement, and appeared to be dead, or nearly so, in the spring, all the plants are alive at this time, but not equally healthy. The Yew has been perfectly healthy all the year; shoots about 2 inches long have been produced from each stem; it is quite as vigorous as one exactly similar planted in the garden. Evergreen Berberry, perfectly healthy, lost all its leaves in the spring, and produced fresh ones quite equal to that in the garden. Portugal Laurel, about the same as when planted, has not grown. Common Laurel, a great many leaves fallen at various times, which have not been reproduced; the garden plant much healthier. Spruce Fir produced young shoots about 2 inches long, which are now green, but the remainder of the plant is brown, and I should think would die, if not removed. Holly very healthy, a little grown, quite equal to the garden plant. Larch grew well at first, but in the summer the leaves were covered with spots of turpentine, and the colour of the leaves was unhealthy; I should doubt whether it would live another year. Sycamore tolerably healthy, but some of the leaves mildewed. Oak and Ash about the same, tolerably healthy. Berberis D. healthy all the year.

Table No. II., in which the amount of water evaporated is divided into periods of four months, shows very clearly the comparative characters of Evergreen and Deciduous trees. Of the six Evergreen plants, the amount of water evaporated during the first four months was 44 per cent. of that evaporated during the following four months; while in the Deciduous plants it was only 14 per cent.: this would account for the large percentage of loss when evergreens are transplanted in winter. In Table IV., where the amount of water evaporated is divided into three portions, the comparative characters of the two descriptions of *plant are still* more clearly shown.

Table I.

Loss of Water, obtained by Weighing various Plants during a Period of Twelve Months.—Actual Results of Loss in Grains.

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
SPRUCE FIR.					
Dec. 22 to Jan. 3	12	4,620	385·0	30·50	1·18
Jan. 3 to Jan. 13	10	1,415	141·5	32·15	0·06
Jan. 13 to Jan. 23	10	2,645	264·5	28·20	0·86
Jan. 23 to Feb. 3	11	2,320	210·9	31·18	0·24
Feb. 3 to Feb. 13	10	3,195	319·5	40·95	1·40
Feb. 13 to Feb. 23	10	3,645	364·5	44·20	2·00
Feb. 23 to Mar. 5	10	2,660	266·0	41·65	1·60
Mar. 5 to Mar. 15	10	3,140	314·0	39·80	3·70
Mar. 15 to Mar. 25	10	3,330	333·0	35·35	4·76
Mar. 25 to Apr. 4	10	6,160	616·0	40·40	5·46
Apr. 4 to Apr. 14	10	3,110	311·0	49·35	2·03
Apr. 14 to Apr. 24	10	2,505	250·5	47·75	2·50
Apr. 24 to May 4	10	3,295	329·5	45·60	9·66
May 4 to May 14	10	2,480	248·0	47·40	3·00
May 14 to May 24	10	2,880	288·0	52·75	4·30
May 24 to June 3	10	4,550	455·0	56·30	5·13
June 3 to June 13	10	5,520	552·0	59·10	8·80
June 13 to June 23	10	8,800	880·0	56·55	9·86
June 23 to July 23	30	17,670	589·0	61·96	4·61
July 23 to Aug. 22	30	11,300	376·6	62·13	2·10
Aug. 22 to Sept. 21	30	11,260	375·3	53·90	4·97
Sept. 21 to Oct. 21	30	11,680	389·3	49·21	2·21
Oct. 21 to Nov. 20	30	4,530	151·0	43·86	1·18
Nov. 20 to Dec. 31	41	1,640	40·0	38·57	0·18
PORTUGAL LAUREL.					
Dec. 22 to Jan. 3	12	3,960	330	30·50	1·18
Jan. 3 to Jan. 13	10	1,300	130	32·15	0·06
Jan. 13 to Jan. 23	10	1,840	184	28·20	0·86
Jan. 23 to Feb. 3	11	1,760	160	31·18	0·24
Feb. 3 to Feb. 13	10	3,550	355	40·95	1·40
Feb. 13 to Feb. 23	10	3,400	340	44·20	2·00
Feb. 23 to Mar. 5	10	3,010	301	41·65	1·60
Mar. 5 to Mar. 15	10	3,440	344	39·80	3·70
Mar. 15 to Mar. 25	10	5,190	519	35·35	4·76
Mar. 25 to Apr. 4	10	4,230	423	40·40	5·46
Apr. 4 to Apr. 14	10	4,740	474	49·35	2·03
Apr. 14 to Apr. 24	10	3,320	332	47·75	2·50
Apr. 24 to May 4	10	3,900	390	45·60	9·66
May 4 to May 14	10	3,510	351	47·40	3·00
May 14 to May 24	10	5,080	508	52·75	4·30
May 24 to June 3	10	8,540	854	56·30	5·13
June 3 to June 13	10	9,120	912	59·10	8·80
June 13 to June 23	10	11,160	1116	56·55	9·86
June 23 to July 23	30	30,390	1013	61·96	4·61
July 23 to Aug. 22	30	31,840	1061·3	62·13	2·10
Aug. 22 to Sept. 21	30	26,670	889	53·90	4·97
Sept. 21 to Oct. 21	30	18,520	617·3	49·21	2·21
Oct. 21 to Nov. 20	30	5,660	188·7	43·86	1·18
Nov. 20 to Dec. 31	41	2,270	55·3	38·57	0·18

TABLE I.—*continued.*

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
EVERGREEN BERBERIS.					
Dec. 22 to Jan. 3	12	1,810	150·8	30·50	1·18
Jan. 3 to Jan. 13	10	745	74·5	32·15	0·06
Jan. 13 to Jan. 23	10	810	81·0	28·20	0·86
Jan. 23 to Feb. 3	11	875	79·5	31·18	0·24
Feb. 3 to Feb. 13	10	1,860	186·0	40·95	1·40
Feb. 13 to Feb. 23	10	2,940	294	44·20	2·00
Feb. 23 to Mar. 5	10	1,670	167	41·65	1·60
Mar. 5 to Mar. 15	10	2,180	218	39·80	3·70
Mar. 15 to Mar. 25	10	3,320	332	35·35	4·76
Mar. 25 to Apr. 4	10	2,660	266	40·40	5·46
Apr. 4 to Apr. 14	10	2,620	262	49·35	2·03
Apr. 14 to Apr. 24	10	3,040	304	47·75	2·50
Apr. 24 to May 4	10	2,330	233	45·60	9·66
May 4 to May 14	10	1,640	164	47·40	3·00
May 14 to May 24	10	2,870	287	52·75	4·30
May 24 to June 3	10	5,950	595	56·30	5·13
June 3 to June 13	10	9,020	902	59·10	8·80
June 13 to June 23	10	7,750	775	56·55	9·86
June 23 to July 23	30	31,160	1038·6	61·96	4·61
July 23 to Aug. 22	30	26,180	872·7	62·13	2·10
Aug. 22 to Sept. 21	30	22,510	750·3	53·90	4·97
Sept. 21 to Oct. 21	30	17,170	572·3	49·21	2·21
Oct. 21 to Nov. 20	30	5,540	184·7	43·86	1·18
Nov. 20 to Dec. 31	41	1,700	41·5	38·57	0·18
YEW.					
Dec. 22 to Jan. 3	12	3,720	310·0	30·50	1·18
Jan. 3 to Jan. 13	10	1,795	179·5	32·15	0·06
Jan. 13 to Jan. 23	10	1,985	198·5	28·20	0·86
Jan. 23 to Feb. 3	11	2,420	220	31·18	0·24
Feb. 3 to Feb. 13	10	3,650	365	40·95	1·40
Feb. 13 to Feb. 23	10	4,630	463	44·20	2·00
Feb. 23 to Mar. 5	10	4,300	430	41·65	1·60
Mar. 5 to Mar. 15	10	4,800	480	39·80	3·70
Mar. 15 to Mar. 25	10	5,370	537	35·35	4·76
Mar. 25 to Apr. 4	10	7,480	748	40·40	5·46
Apr. 4 to Apr. 14	10	7,090	709	49·35	2·03
Apr. 14 to Apr. 24	10	8,160	816	47·75	2·50
Apr. 24 to May 4	10	8,700	870	45·60	9·66
May 4 to May 14	10	4,450	445	47·40	3·00
May 14 to May 24	10	7,020	702	52·75	4·30
May 24 to June 3	10	9,750	975	56·30	5·13
June 3 to June 13	10	8,505	850·5	59·10	8·80
June 13 to June 23	10	9,555	955·5	56·55	9·86
June 23 to July 23	30	30,370	1012·3	61·96	4·61
July 23 to Aug. 22	30	24,285	809·5	62·13	2·10
Aug. 22 to Sept. 21	30	21,845	728·2	53·90	4·97
Sept. 21 to Oct. 21	30	20,060	668·6	49·21	2·21
Oct. 21 to Nov. 20	30	6,590	219·6	43·86	1·18
Nov. 20 to Dec. 31	41	730	17·8	38·57	0·18

TABLE I.—*continued.*

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
HOLLY.					
Dec. 22 to Jan. 3	12	1,800	150·0	30·50	1·18
Jan. 3 to Jan. 13	10	610	61·0	32·15	0·06
Jan. 13 to Jan. 23	10	845	84·5	28·20	0·86
Jan. 23 to Feb. 3	11	1,125	102·2	31·18	0·24
Feb. 3 to Feb. 13	10	2,070	207	40·95	1·40
Feb. 13 to Feb. 23	10	2,760	276	44·20	2·00
Feb. 23 to Mar. 5	10	1,820	182	41·65	1·60
Mar. 5 to Mar. 15	10	2,640	264	39·80	3·70
Mar. 15 to Mar. 25	10	3,200	320	35·35	4·76
Mar. 25 to Apr. 4	10	2,590	259	40·40	5·46
Apr. 4 to Apr. 14	10	2,620	262	49·35	2·03
Apr. 14 to Apr. 24	10	1,700	170	47·75	2·50
Apr. 24 to May 4	10	2,300	230	45·60	9·66
May 4 to May 14	10	1,400	140	47·40	3·00
May 14 to May 24	10	2,130	213	52·75	4·30
May 24 to June 3	10	3,225	322·5	56·30	5·13
June 3 to June 13	10	2,915	291·5	59·10	8·80
June 13 to June 23	10	2,370	237	56·55	9·86
June 23 to July 23	30	9,140	304·7	61·96	4·61
July 23 to Aug. 22	30	10,100	336·6	62·13	2·10
Aug. 22 to Sept. 21	30	7,150	238·3	53·90	4·97
Sept. 21 to Oct. 21	30	7,820	260·6	49·21	2·21
Oct. 21 to Nov. 20	30	3,780	126	43·86	1·18
Nov. 20 to Dec. 31	41	1,500	37·6	38·57	0·18
COMMON LAUREL.					
Dec. 22 to Jan. 3	12	2,718	226·5	30·50	1·18
Jan. 3 to Jan. 13	10	1,802	180·2	32·15	0·06
Jan. 13 to Jan. 23	10	1,895	189·5	28·20	0·86
Jan. 23 to Feb. 3	11	2,415	219·5	31·18	0·24
Feb. 3 to Feb. 13	10	3,715	371·5	40·95	1·40
Feb. 13 to Feb. 23	10	3,895	389·5	44·20	2·00
Feb. 23 to Mar. 5	10	3,250	325	41·65	1·60
Mar. 5 to Mar. 15	10	4,270	427	39·80	3·70
Mar. 15 to Mar. 25	10	4,910	491	35·35	4·76
Mar. 25 to Apr. 4	10	4,890	489	40·40	5·46
Apr. 4 to Apr. 14	10	5,460	546	49·35	2·03
Apr. 14 to Apr. 24	10	4,220	422	47·75	2·50
Apr. 24 to May 4	10	7,160	716	45·60	9·66
May 4 to May 14	10	8,240	824	47·40	3·00
May 14 to May 24	10	12,375	1237·5	52·75	4·30
May 24 to June 3	10	13,795	1379·5	56·30	5·13
June 3 to June 13	10	12,590	1259	59·10	8·80
June 13 to June 23	10	11,590	1159	56·55	9·86
June 23 to July 23	30	37,450	1248·3	61·96	4·61
July 23 to Aug. 22	30	26,640	888	62·13	2·10
Aug. 22 to Sept. 21	30	22,940	764·6	53·90	4·97
Sept. 21 to Oct. 21	30	16,520	550·6	49·21	2·21
Oct. 21 to Nov. 20	30	6,110	203·6	43·86	1·18
Nov. 20 to Dec. 31	41	2,030	49·5	38·57	0·18

TABLE I.—*continued.*

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
ILEX.					
Dec. 22 to Jan. 3	12	980	81·7	30·50	1·18
Jan. 3 to Jan. 13	10	370	37	32·15	0·06
Jan. 13 to Jan. 23	10	820	82	28·20	0·86
Jan. 23 to Feb. 3	11	580	52·7	31·18	0·24
Feb. 3 to Feb. 13	10	240	24	40·95	1·40
Feb. 13 to Feb. 23	10	1,350	135	44·20	2·00
Feb. 23 to Mar. 5	10	580	58	41·65	1·60
Mar. 5 to Mar. 15	10	1,130	113	39·80	3·70
Mar. 15 to Mar. 25	10	2,600	260	35·35	4·76
Mar. 25 to Apr. 4	10	1,020	102	40·40	5·46
Apr. 4 to Apr. 14	10	1,130	113	49·35	2·03
Apr. 14 to Apr. 24	10	160	16	47·75	2·50
Apr. 24 to May 4	10	330	33	45·60	9·66
May 4 to May 14	10	240	24	47·40	3·00
May 14 to May 24	10	260	26	52·75	4·30
May 24 to June 3	10	650	65	56·30	5·13
June 3 to June 13	10	234	23·4	59·10	8·80
June 13 to June 23	10	296	29·6	56·55	9·86
June 23 to July 23	30	480	16	61·96	4·61
July 23 to Aug. 22	30	600	20	62·13	2·10
Aug. 22 to Sept. 21	30	180	6	53·90	4·97
Sept. 21 to Oct. 21	30	800	26·6	49·21	2·21
Oct. 21 to Nov. 20	30	140	4·6	43·86	1·18
Nov. 20 to Dec. 31	41	360	8·8	38·57	0·18
LARCH.					
Dec. 22 to Jan. 3	12	640	53·3	30·50	1·18
Jan. 3 to Jan. 13	10	100	10·	32·15	0·06
Jan. 13 to Jan. 23	10	125	12·5	28·20	0·86
Jan. 23 to Feb. 3	11	215	19·5	31·18	0·24
Feb. 3 to Feb. 13	10	610	61	40·95	1·40
Feb. 13 to Feb. 23	10	1,070	107	44·20	2·00
Feb. 23 to Mar. 5	10	450	45	41·65	1·60
Mar. 5 to Mar. 15	10	1,040	104	39·80	3·70
Mar. 15 to Mar. 25	10	2,040	204	35·35	4·76
Mar 25 to Apr. 4	10	1,440	144	40·40	5·46
Apr. 4 to Apr. 14	10	1,580	158	49·35	2·03
Apr. 14 to Apr. 24	10	2,260	226	47·75	2·50
Apr. 24 to May 4	10	960	96	45·60	9·66
May 4 to May 14	10	720	72	47·40	3·00
May 14 to May 24	10	1,270	127	52·75	4·30
May 24 to June 3	10	1,680	168	56·30	5·13
June 3 to June 13	10	2,160	216	59·10	8·80
June 13 to June 23	10	3,000	300	56·55	9·86
June 23 to July 23	30	16,690	556·3	61·96	4·61
July 23 to Aug. 22	30	26,050	868·3	62·13	2·10
Aug. 22 to Sept. 21	30	24,850	828·3	53·90	4·97
Sept. 21 to Oct. 21	30	21,580	719·3	49·21	2·21
Oct 21 to Nov. 20	30	3,320	110·6	43·86	1·18
Nov. 20 to Dec. 31	41	450	11·0	38·57	0·18

TABLE I.—*continued.*

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
OAK.					
Dec. 22 to Jan. 3	12	660	55	30·50	1·18
Jan. 3 to Jan. 13	10	150	15	32·15	0·06
Jan. 13 to Jan. 23	10	125	12·5	28·20	0·86
Jan. 23 to Feb. 3	11	155	14·1	31·18	0·24
Feb. 3 to Feb. 13	10	190	19	40·95	1·40
Feb. 13 to Feb. 23	10	200	20	44·20	2·00
Feb. 23 to Mar. 5	10	390	39	41·65	1·60
Mar. 5 to Mar. 15	10	790	79	39·80	3·70
Mar. 15 to Mar. 25	10	2,110	211	35·35	4·76
Mar. 25 to Apr. 4	10	1,290	129	40·40	5·46
Apr. 4 to Apr. 14	10	900	90	49·35	2·03
Apr. 14 to Apr. 24	10	1,550	155	47·75	2·50
Apr. 24 to May 4	10	10	1	45·60	9·66
May 4 to May 14	10	210	21	47·40	3·00
May 14 to May 24	10	270	27	52·75	4·30
May 24 to June 3	10	1,220	122	56·30	5·13
June 3 to June 13	10	1,590	159	59·10	8·80
June 13 to June 23	10	2,390	239	56·55	9·86
June 23 to July 23	30	11,710	390·3	61·96	4·61
July 23 to Aug. 22	30	17,650	588·3	62·13	2·10
Aug. 22 to Sept. 21	30	17,730	591	53·90	4·97
Sept. 21 to Oct. 21	30	13,950	465	49·21	2·21
Oct. 21 to Nov. 20	30	4,460	148·6	43·86	1·18
Nov. 20 to Dec. 31	41	890	21·7	38·57	0·18
DECIDUOUS BERBERIS.					
Dec. 22 to Jan. 3	12	820	68·3	30·50	1·18
Jan. 3 to Jan. 13	10	155	15·5	32·15	0·06
Jan. 13 to Jan. 23	10	190	19	28·20	0·86
Jan. 23 to Feb. 3	11	185	16·8	31·18	0·24
Feb. 3 to Feb. 13	10	530	53	40·95	1·40
Feb. 13 to Feb. 23	10	825	82·5	44·20	2·00
Feb. 23 to Mar. 5	10	375	37·5	41·65	1·60
Mar. 5 to Mar. 15	10	1,240	124	39·80	3·70
Mar. 15 to Mar. 25	10	2,460	246	35·35	4·76
Mar. 25 to Apr. 4	10	3,350	335	40·40	5·46
Apr. 4 to Apr. 14	10	1,080	108	49·35	2·03
Apr. 14 to Apr. 24	10	530	53	47·75	2·50
Apr. 24 to May 4	10	2,370	237	45·60	9·66
May 4 to May 14	10	3,180	318	47·40	3·00
May 14 to May 24	10	5,895	589·5	52·75	4·30
May 24 to June 3	10	9,105	910·5	56·30	5·13
June 3 to June 13	10	9,514	951·4	59·10	8·80
June 13 to June 23	10	10,236	1023·6	56·55	9·86
June 23 to July 23	30	31,870	1062·3	61·96	4·61
July 23 to Aug. 22	30	30,020	1000·6	62·13	2·10
Aug. 22 to Sept. 21	30	32,990	1099·6	53·90	4·97
Sept. 21 to Oct. 21	30	28,770	959	49·21	2·21
Oct. 21 to Nov. 20	30	3,770	125·6	43·86	1·18
Nov. 20 to Dec. 31	41	550	13·4	38·57	0·18

TABLE I.—*continued.*

Dates.	Number of Days.	Number of Grains Evaporated.	Loss per Diem.	Mean Temperature of Day; Fahr.	Hygrometer.
ASH.					
Dec. 22 to Jan. 3	12	1,290	107·5	30·50	1·18
Jan. 3 to Jan. 13	10	110	11	32·15	0·06
Jan. 13 to Jan. 23	10	100	10	28·20	0·86
Jan. 23 to Feb. 3	11	100	9·1	31·18	0·24
Feb. 3 to Feb. 13	10	690	69	40·95	1·40
Feb. 13 to Feb. 23	10	390	39	44·20	2·00
Feb. 23 to Mar. 5	10	280	28	41·65	1·60
Mar. 5 to Mar. 15	10	830	83	39·80	3·70
Mar. 15 to Mar. 25	10	1,830	183	35·35	4·76
Mar. 25 to Apr. 4	10	1,290	129	40·40	5·46
Apr. 4 to Apr. 14	10	650	65	49·35	2·03
Apr. 14 to Apr. 24	10	340	34	47·75	2·50
Apr. 24 to May 4	10	345	34·5	45·60	9·66
May 4 to May 14	10	535	53·5	47·40	3·00
May 14 to May 24	10	1,560	156	52·75	4·30
May 24 to June 3	10	5,560	556	56·30	5·13
June 3 to June 13	10	7,850	785	59·10	8·80
June 13 to June 23	10	10,360	1036	56·55	9·86
June 23 to July 23	30	30,210	1007	61·96	4·61
July 23 to Aug. 22	30	25,500	850	62·13	2·10
Aug. 22 to Sept. 21	30	21,500	716·6	53·90	4·97
Sept. 21 to Oct. 21	30	2,400	80	49·21	2·21
Oct. 21 to Nov. 20	30	840	28	43·86	1·18
Nov. 20 to Dec. 31	41	720	17·6	38·57	0·18
SYCAMORE.					
Dec. 22 to Jan. 3	12	620	51·7	30·50	1·18
Jan. 3 to Jan. 13	10	240	24	32·15	0·06
Jan. 13 to Jan. 23	10	140	14	28·20	0·86
Jan. 23 to Feb. 3	11	160	14·5	31·18	0·24
Feb. 3 to Feb. 13	10	250	25	40·95	1·40
Feb. 13 to Feb. 23	10	610	61	44·20	2·00
Feb. 23 to Mar. 5	10	890	89	41·65	1·60
Mar. 5 to Mar. 15	10	1,280	128	39·80	3·70
Mar. 15 to Mar. 25	10	2,380	238	35·35	4·76
Mar. 25 to Apr. 4	10	1,430	143	40·40	5·46
Apr. 4 to Apr. 14	10	1,650	165	49·35	2·03
Apr. 14 to Apr. 24	10	80	8	47·75	2·50
Apr. 24 to May 4	10	200	20	45·60	9·66
May 4 to May 14	10	210	21	47·40	3·00
May 14 to May 24	10	720	72	52·75	4·30
May 24 to June 3	10	4,420	442	56·30	5·13
June 3 to June 13	10	6,360	636	59·10	8·80
June 13 to June 23	10	8,070	807	56·55	9·86
June 23 to July 23	30	27,410	913·6	61·96	4·61
July 23 to Aug. 22	30	27,990	933	62·13	2·10
Aug. 22 to Sept. 21	30	26,890	896·3	53·90	4·97
Sept. 21 to Oct. 21	30	19,150	638·3	49·21	2·21
Oct. 21 to Nov. 20	30	1,580	52·7	43·86	1·18
Nov. 20 to Dec. 31	41	680	16·6	38·57	0·18

Table II.

Water Evaporated in periods of Four Months, by various Plants—Grains.

	December 22 to April 24.	April 24 to August 22.	August 22 to December 31.
Spruce Fir	38,725	56,595	29,110
Portugal Laurel	39,740	104,040	53,022
Evergreen Berberis ..	24,530	85,910	46,920
Yew	55,400	102,635	49,225
Holly	23,780	33,580	20,250
Common Laurel	43,440	129,840	47,600
Ilex	10,970	3,090	1,480
Larch	11,570	52,530	50,200
Oak	8,510	35,050	37,030
Deciduous Berberis ..	11,740	102,190	66,080
Ash	7,900	81,920	25,470
Sycamore	9,730	75,380	48,300

Table III.

Water Evaporated in Twelve Months, by various Plants—Grains.

	Water supplied to Soil.	Water obtained from Soil.	Total Evaporated.
Spruce Fir	91,400	33,030	124,430
Portugal Laurel	156,400	40,502	196,902
Evergreen Berberis ..	123,900	33,460	157,360
Yew	171,400	35,860	207,260
Holly	61,400	16,210	77,610
Common Laurel	181,400	39,480	220,880
Ilex	13,400	2,100	15,540
Larch	87,400	26,900	114,300
Oak	57,400	23,190	80,590
Deciduous Berberis ..	137,400	42,610	180,010
Ash	102,400	12,890	115,290
Sycamore	97,400	36,010	133,410

Table IV.

Table showing the Periods of the year in which Evergreen and Deciduous Plants Evaporate 100 Parts of Water.

	Evergreen.	Deciduous.
Four months to April 24	23	8
,, August 22	52½	56
,, December 31	24½	36
	100	100

Note upon the Preceding Experiments.

The evaporating power of the leaves is one of the most important properties of plants, for on the healthy performance of this function depend not merely the vigour and development of the plant, but also, indeed, its very existence. Every new fact, therefore, which in any way tends to elucidate the chemical or physiological nature of the leaves, or which throws light upon the mode in which they act, and the effects produced by the various agents to the influence of which they are naturally subject, is highly interesting. The preceding experiments were undertaken with a view to ascertain the ratio which exists between the evaporating power of different leaves, contrasting together in particular those of Evergreens and those of Deciduous plants. Before making one or two remarks which these experiments suggest, it will, perhaps, not be out of place to say a few words respecting some former investigations on the same subject.

It is more than a hundred and fifty years since Dr. Woodward published, in the twentieth volume of the 'Philosophical Transactions of the Royal Society,' an account of some experiments on vegetation, having for their especial object to determine the evaporating power of the leaves. These experiments were curious, and excited a good deal of interest at the time the results were published. Some of the conclusions drawn from them were tolerably accurate, but from the vague and uncertain views which were then generally entertained respecting the growth and nourishment of plants, the very facts themselves became, to a very great extent, mystified and confused, so that their practical value was greatly diminished.

Dr. Woodward's experiments were made with weighed bottles of water, having a piece of parchment tied over their mouths, in which a small aperture was made, just sufficient to admit the stem of a plant, but not so small as to confine or impede its growth. As the water evaporated, fresh was added from time to time, a register being kept of the quantity added, as well as of that which was lost by evaporation. The plants were placed side by side in a window, where they were equally exposed to sunshine; and the experiment was continued from the 20th of July, 1691, to the 5th of October in the same year. The following was the result of one of these comparative experiments:—

	Original Weight.	Final Weight.	Water Evaporated.
	Grains.	Grains.	Grains.
Spearmint, in spring water ..	27	42	2558
Ditto, in rain water	28	45	3004
Ditto, in Thames water	28	54	2493
Nightshade, in spring water ..	49	106	3708
Lathyris, in spring water	98	101	2501

Proceeding to compare together the increase in weight of the plant with the quantity of water it had given off, Dr. Woodward showed that in the case of the three plants of Spearmint, it was respectively as 1 to 170, to 171, and to 95; whilst in the instance of the Nightshade it was as 1 to 65, and in that of the Lathyris as 1 to 714. It is evident, however, that from such experiments no very satisfactory or accurate conclusion could well be drawn; they were repeated and varied in different ways, and similar results were obtained. One of the most curious of these experiments was an attempt to ascertain more exactly the precise effect of different kinds of water on the growth and evaporating power of the same plant; in this case six plants of Spearmint were suffered to grow in weighed bottles of water for eight weeks; the results were as follows:—

Spearmint.	Original Weight.	Increase.	Water Evaporated.	Ratio of Increase to Evaporation.
	Grains.	Grains.	Grains.	
1. In Hyde Park water	127	128	14,190	1 to 110
2. Ditto	110	139	13,140	1 to 94
3. Ditto, with ½ an oz. of soil	76	168	10,731	1 to 63
4. Ditto, with ½ an oz. of garden soil ..	92	284	14,950	1 to 52
5. Distilled water	114	41	8,803	1 to 214
6. Hyde Park water, concentrated by evaporation	81	94	4,344	1 to 46

It was the common belief of many naturalists at the time that the increase in weight of plants was in direct proportion to the quantity of water which passed through them, or rather to the proportion of it which became fixed in their organs in the process of being absorbed by the roots and given off by the leaves. In the experiments just mentioned, the last plant increased most in proportion to the quantity of water evaporated, but the fourth was the one which grew most luxuriantly, and it was also the one which absorbed the largest quantity of water in proportion to its weight. The plant fed with distilled water grew least of all, whilst that fed with spring water containing a portion of garden soil was by far the most flourishing.

These experiments of Woodward led Dr. Stephen Hales to make a number of curious and interesting observations on the evaporating power of the leaves of plants, which he published in 1727, in the first volume of his celebrated 'Statical Essays.' Those which more immediately relate to the present subject will be found in the first chapter, "on the quantity of moisture imbibed and perspired by plants and trees." Hales's most celebrated experiment was made in 1724 with a healthy full-grown Sunflower, more than a yard high, and which had been purposely planted when young in a suitable flowerpot. The mode in which the experiment was conducted is best given in his own words:—"I covered the pot with a plate of thin milled lead, and cemented all the joints fast, so that no vapour could pass, but only air, through a small glass tube, 9 inches long, which was fixed purposely near the stem of the plant, to make a free communication with the outward air and that under the leaden plate. I cemented also another short glass tube into the plate, 2 inches long, and 1 inch in diameter. Through this tube I watered the plant, and then stopped it up with a cork; I also stopped up the hole at the bottom of the pot with a cork."

Matters being thus arranged, the plant received a weighed supply of water, and being itself weighed twice a day for a fortnight, the rate of evaporation was easily observed. By another comparative experiment Dr. Hales ascertained the quantity of water evaporated every day by the porous earthen pot, and subtracted it from the whole daily loss sustained by the Sunflower. The result showed that on an average the plant evaporated 20 ounces, or 34 cubic inches of water, in a twelve hours' day; the maximum proportion being 30 ounces. This was certainly a very interesting and remarkable experiment, and it was rendered all the more so by the careful and minute details which accompanied its publication; including the bulk and length of the roots, and the exact size of the leaves. Hales also measured the rate of evaporation of a Cabbage, a Vine, a young Apple-tree, and a Lemon-tree. The result of these experiments is expressed in the following Table:—

	Entire Surface of Leaves.	Water Perspired in 12 hours.	Ratio of Evaporation to Surface of Plant.
	Square inches.	Ounces.	
Sunflower ..	5616	20	$\frac{1}{281}$
Cabbage	2736	19	$\frac{1}{144}$
Vine	1820	$5\frac{1}{2}$	$\frac{1}{331}$
Apple-tree ..	1589	9	$\frac{1}{176}$
Lemon-tree ..	2557	$10\frac{1}{3}$	$\frac{1}{248}$

The practical conclusion drawn from these experiments was, that the Cabbage evaporated the greatest quantity of water, and the Lemon-tree the least. On repeating it with other plants Dr. Hales found that in all cases evergreens perspired less than those plants which shed their leaves in the winter, a fact which he endeavoured to explain by observing, that "as they perspire less, so they are better able to survive the winter's cold." At the same time that he made these experiments he also made a number of other highly interesting ones, on the force with which plants absorb water, and many similar points connected with this part of their economy.

A third series of experiments was made by Mr. Miller in 1726, at the Chelsea Botanic Garden, at the suggestion of Dr. Hales, in which the subjects of experiment were a Musa, an Aloe, and an Apple-tree. The plants were grown in glazed earthenware pots, made without any holes at the bottom, so that there was no need to make any correction for the water lost by evaporation; the plants were weighed three times a day for some weeks, and the thermometer was noted at each weighing. The chief facts observed were, that the plants perspired more in the morning than in the afternoon; that they very often absorbed moisture by the leaves during the night; and that the proportion perspired was generally in direct proportion to the temperature of the day.

These simple experiments are, all of them, perfectly satisfactory, and, as far as they go, are no doubt quite trustworthy. It is remarkable that during the last one hundred and thirty years hardly a single new fact of much importance has been added to this department of vegetable physiology, and that our knowledge of this important branch of the economy of vegetation is very little extended beyond what it was at the time of Hales. One reason of this certainly is, that the observers who followed him began to refine upon the simple mode of experimenting which he employed, and introduced complicated and unnatural forms of experiment, the results of which are, for the most part, of but little value. Thus the numerous and laborious experiments of Bonnet, undertaken chiefly at the suggestion of Calandrini, to ascertain the relative power of absorbing moisture by the superior and inferior surfaces of the leaf, were far from satisfactory; because, though his object was to measure the power of absorbing aqueous vapour, his experiments in fact all had reference to a different point, namely, the power of the leaves to absorb water, when placed in contact with it, by the upper or lower surface. The experiments of Bonnet, even on the direct absorption of water, do not really give a true indication of the evaporating power of the leaves, because they were made on single leaves and not on

entire plants; they consequently did not fairly represent the sound and perfect leaves of a growing plant.

The very numerous series of experiments, on the evaporation from leaves, detailed in the preceding pages, are highly valuable, because they extend over a considerable period of time, and therefore are less under the influence of the various interfering causes which generally introduce errors into such investigations. At the same time, however, they are by no means unexceptionable, for there are several matters connected with them which are open to doubt and uncertainty. The first great condition of all such experiments in every case is, that the plants must be brought into a healthy condition at the commencement of the experiment, and kept in a healthy state all through it; if the plant is rendered sickly and unhealthy by the conditions of the experiment, it is plain that, the circumstances being forced and unnatural, they cannot be expected to yield satisfactory results. Now, in the preceding experiments, the plants were unquestionably injured by the treatment they received, and, what is still worse, they were injured to an unequal extent, some of them being rendered far more sickly than the others. If means cannot be devised to prevent the evaporation of moisture from the surface of the soil without tying bandages round the stem, it is far better to calculate the amount of water thus lost, as Hales did, and subtract it from the total loss at each weighing. If all the other circumstances are perfectly similar, this loss would not vary much; it would be pretty nearly constant with each of the different plants. It is also to be remarked, that in thus absolutely preventing all evaporation from the enclosed soil, excepting that which took place through the leaves of the plant, the soil was altogether cut off from contact with the external air, and thus another, and by no means unimportant, condition was introduced.

In experiments of this sort it is very desirable not to commence them the very day the plants have been transplanted; some little time should be allowed to elapse before the experiment is begun, so that the plants may become accustomed to the new conditions under which they are placed; and in every case where possible two or three similar plants should be taken for each experiment, instead of single ones.

For the most part the experimental results are pretty nearly what might have been expected, though of course there are exceptions and irregularities, which must be attributed to special interfering causes. There would seem to be a remarkable difference between the several plants, as regards the relation existing between the temperature and the rate of evaporation, independently *of the dryness* or moisture of the air. On comparing the tables

together, it will be found that in the case of the Portugal Laurel, Holly, Larch, and Sycamore, the maximum evaporation occurs at the same time as the maximum of temperature, namely, between the 23rd of July and the 22nd of August. This, however, is not the case with the other plants. In the case of the Oak, and the Deciduous Berberis, the maximum evaporation occurs after the greatest heat; the greatest quantity of water being evaporated between the 22nd of August and the 21st of September, though the average temperature then was more than 8° lower than it had been during the previous four weeks. Exactly the reverse is the case with the remaining plants, for the maximum evaporation with the Spruce-Fir, Evergreen Berberis, Yew, Laurel, and Ash, in each instance preceded the maximum of heat. On referring to the table showing the evaporation from the Evergreen Berberis, it will be found that from the 23rd of June to the 23rd of July, when the average temperature was below 62°, the daily loss of water was 1038 grains, whilst in the following month, though the thermometer was then above 62°, the daily evaporation was only 872 grains. A similar effect may be observed with regard to the Yew. In July, with a temperature below 62°, the daily loss was 1012 grains; in August, with an average temperature above 62°, the daily evaporation was only 809 grains. It is evident, therefore, from these experiments, that evaporation is not a mere index of temperature, but that it depends on vitality, influenced by heat, light, and other causes.

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ON

ICULTURAL CHEMISTRY,

ESPECIALLY IN RELATION TO THE

ERAL THEORY OF BARON LIEBIG.

By J. B. LAWES,
OF ROTHAMSTED,
AND DR. J. H. GILBERT.

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ON

AGRICULTURAL CHEMISTRY.

It was under the auspices of the British Association that Professor Liebig in the year 1840 first promulgated his views on the subject of Agricultural Chemistry; and however much some may be disposed to differ from him in opinion on special points therein treated of, few we presume will deny that from the appearance of the first edition of Professor Liebig's work on 'Organic Chemistry in its relations to Agriculture and Physiology' we may date a spirit of investigation into Agricultural Chemistry such as had not previously been manifested in this country. Indeed, we conceive that in looking back to the words of his preface in 1840, wherein he says, "I shall be happy if I succeed in attracting the attention of men of science to subjects which so well merit to engage their talents and energies,"—in this respect, at least, Professor Liebig must feel that his efforts have been rewarded far beyond what his most sanguine expectation could at the time have led him to hope for. It could scarcely be expected, however, that with the progress of inquiry, such as is here invited, there should not result from time to time some, and perhaps material, modifications on questions which it is admitted the facts already at command were not competent satisfactorily to solve; indeed, if it were not so, if no further facts were requisite, and the views as then put forth were all and in their manifold detail already fully substantiated, where the necessity for further investigation of the subject? Surely it would be labour lost!

Professor Liebig has indeed himself contributed to the development of the subject, in the several succeeding editions of his works; and also in his 'Letters on Chemistry,' and in other publications; and he has, in a new and enlarged edition of the second-mentioned work, namely, his 'Letters on Chemistry,' pub-

Prussia, has published the results of many analyses of soils. The truth is, that little is as yet known of what a soil either is or ought to be, in a chemical point of view; but when we call to mind the investigations of Professor Mulder, in relation to the organic acids found in soils, and of Mr. Way and others, as to the chemical and physical properties of soils, in relation to the atmosphere, and to saline substances exposed to their action in solution, we may at least anticipate for chemistry that she will ere long throw important light on this interesting but intricate subject.

In our field experiments, then, we have been satisfied with preserving specimens of the soils which were to be the subjects of them, and have sought to ascertain their deficiency, in regard to the production of different crops, by means which we conceive to be not only far more manageable, but in every way more conclusive and satisfactory in their result.

To illustrate—What is termed a rotation of crops is at least of such universality in the farming of Great Britain, that any investigation in relation to the agriculture of that country may safely be grounded on the supposition of its adoption. Let us, then, direct attention for a moment to some of the chief features of rotation. What is called a *course* of rotation is the period of years which includes the circle of all the different crops grown in that rotation or alternation. The crops which thus succeed each other, and constitute a rotation, may be two, three, four, or more, varying with the nature of the soil and the judgment of the farmer; but, whatever *course* be adopted, no individual crop — wheat, for example—is grown immediately succeeding one of the same description, but it is sown again only after some other crops have been grown, and at such a period of the rotation, indeed, as by experience it is known that the soil will, by direct manure or other means, have recovered its capability of producing a profitable quantity of the crop in question.

On carefully considering these established and well-known facts of agriculture, it appeared to us that, by taking soils either at the end of the rotation, or at least at that period of it when in the ordinary course of farming farm-yard-manure would be added before any further crop would be grown, we should then have the soils in what may be termed a *normal*, or, perhaps better still, a *practically* and *agriculturally exhausted state*.

Now, if it is found, in the experience of the farmer, that land of any given quality with which he is well acquainted, will not when in this condition of *practical exhaustion* yield the quantity he usually obtains from it of any particular crop, but that after applying farm-yard manure it will do so, it is evident that if we supply to different plots of this *exhausted land* the constituents of farm-yard manure, both individually and combined, and if

by the side of these plots we also grow the crop both without manure of any kind and with farm-yard manure, we shall, in the comparative results obtained, have a far more satisfactory solution of the question as to what constituents were, in this ordinary course of agriculture, most in defect in respect to the production of the particular crop experimented upon, than any analysis of the soil could have given us. In other words, we should have before us very good ground for deciding to which of the constituents of the farm-yard manure the increased produce was mainly due on the plot provided with it, in the case of the particular crop: not so, however, unless the soil had been so far exhausted by previous cropping as to be considered *practically* unfit for the growth of the crop without manure. We lay particular stress on this point, because we believe that the vast discrepancy in the results of comparative trials with different manures, by different experimenters, arises more from irregularity in what may be called the *floating* capital of the soil than from irregularities in the original character of the soil itself, or from any other cause—unless we include the frequent faulty methods of application.

It is, then, by this *synthetic* rather than by the analytic method that we have sought our results; and in the carrying out of our object we have taken *Wheat* as the type of the cereal crops, *Turnips* as the type of the *root crops*, and *Beans* as the representative of the Leguminous corn crop, most frequently entering into rotation: and having selected for each of these a field which, agriculturally considered, was *exhausted*, we have grown the same description of crop upon the same land, year after year, with different chemical manures, and in each case with one plot or more continuously unmanured, and one supplied every year with a fair quantity of farm-yard manure.

In this way 14 acres have been devoted to the continuous growth of *Wheat* since 1843, 8 acres to the continuous growth of *Turnips* from the same date, and 5 to 6 acres to that of Leguminous corn crops since 1847. And of field experiments, besides these—which amount in each year to from 30 to 40 on Wheat, upwards of 90 on Turnips, and 20 to 30 on Beans—others have been made, viz., some on the growth of Clover, and some in relation to the chemical circumstances involved in an actual course of rotation, comprising Turnips, Barley, Clover, and Wheat, grown in the order in which they are here stated.

It may be stated, too, that in addition to these experiments on wheat and the other crops usually grown upon the farm, as above referred to, we have for several years been much occupied also with the subject of the feeding of animals—viz. Bullocks, Sheep, and Pigs—as well as in investigating the functional actions of the

growing plant in relation to the soil and atmosphere; and in connexion with each of these subjects much laboratory labour has constantly been in progress.

The scope and object of our investigation has been therefore to examine, in the field, the feeding-shed, and the laboratory, into the chemical circumstances connected with the agriculture of Great Britain in its four main features; namely—

First, the production of the Cereal grain crops;
Secondly, that of Root crops;
Thirdly, that of the Leguminous corn and Fodder crops; and,
Fourthly, and lastly, that of the consumption of food on the farm for its double produce of Meat and Manure.

So much then for the rationale and general plan of the experiments themselves, and we now propose to call attention to some of the results which they have afforded us.

Hitherto only part of the results of the wheat experiments of the harvests of 1844, 1845, and 1846, and of these seasons only, have been published; those on turnips, only for the seasons 1843, 1844, and 1845; those on the leguminous crops not at all as yet; and those on feeding, only as far as sheep are concerned, and chiefly too in relation to the one point only of the increase of *live weight* obtained from a given quantity of food, or its constituents. Of the laboratory results, but few have been given in relation to any one of these branches up to the present time. The vast accumulation of results, indeed, will necessarily still further postpone the publication of them in any extended form; and hence it seems the more desirable to take advantage of the present opportunity to attempt to bring together into one view some of the general indications which have been arrived at in relation to a few important points.

With this view, it is to the field experiments on wheat that we shall chiefly confine our attention on this occasion; for wheat, which constitutes the principal food of our population, is with the farmer the most important crop in his rotation, all others being considered more or less subservient to it; and it is, too, in reference to the production of this crop in agricultural quantity that the mineral theory of Baron Liebig is perhaps more prominently at fault than in that of any other.

It is true that, in the case of vegetation in a native soil, unaided by art, the mineral constituents of the plants being furnished from the soil, the atmosphere is found to be a *sufficient* source of the nitrogen and carbon; and it is the supposition that these circumstances of *natural vegetation* apply equally to the various crops when grown *under cultivation* that has *led Baron Liebig* to suggest that, if by artificial means we

accumulate within the soil itself a sufficiently liberal supply of those constituents found in the ashes of the plant—essentially soil constituents, we shall by this means be able in all cases to increase thereby the assimilation of the vegetable or atmospheric constituents in a degree sufficient for agricultural purposes. But agriculture is itself an *artificial* process; and it will be found that, as regards the production of wheat more especially, it is only by the accumulation within the soil itself of nitrogen, *naturally* derived from the atmosphere, rather than of the peculiarly soil-constituents, that our crops of it can be increased. Mineral substances will indeed materially develop the accumulation of vegetable or atmospheric constituents when applied to *some* of the crops of rotation; and it is thus chiefly that these crops become subservient to the growth of the cereal grains; but even in these cases it is not the constituents, *as found collectively in the ashes of the plants to be grown*, that are the most efficient in this respect; nor can the demand which we find thus made for the production of crops in *agricultural quantity* be accounted for by the mere idea of supplying the *actual* constituents of the crop. It would seem, therefore, that we can only arrive at correct ideas in agriculture by a close examination of the actual circumstances of growth of each particular crop when grown under cultivation. We now turn to the consideration of our experiments upon this subject.

It has been said that all the experimental fields were selected when they were in a state of agricultural exhaustion. The wheat-field, however, after having been manured in the usual way for turnips at the commencement of the previous rotation, had then grown barley, peas, wheat, and oats, without any further manuring; so that when taken for experiment in 1844, it was, as a grain-producer, considerably more exhausted than would ordinarily be the case. It was, therefore, in a most favourable condition for the purposes of our experiment.

In the first experimental season, the field of 14 acres was divided into about 20 plots, and it was by the *mineral theory* that we were mainly guided in the selection of manures; mineral manures were therefore employed in the majority of cases. *Ammonia*, on the other hand, being then considered as of less importance, was used in a few instances only, and in these in very insignificant quantities. Rape-cake, as being a well-recognised manure, and calculated to supply—besides some minerals and nitrogen—a certain quantity of *carbonaceous* substance in which both corn and straw so much abound, was also added to one or two of the plots.

The results of this first season (1844) having already been pretty fully detailed in this Journal, we can only give a summary of them in this place:—

TABLE I.*

Harvest 1844. Summary. (See first section of diagram I., opposite p. 14.)

Description of the Manures.	Dressed Corn per Acre, in Bushels and Pecks.		Total Corn per Acre, in lbs.	Straw per Acre, in lbs.
	bush.	pecks.	lbs.	lbs.
Plot 3. Unmanured	16	0	923	1120
,, 2. 14 tons of farm-yard manure	22	0	1276	1476
,, 4. The ashes of 14 tons of farm-yard manure.	16	0	888	1104
,, 8. *Minimum* produce of 9 plots with artificial mineral manures:— Superphosphate lime 350 lbs. Phosphate of potass 364 lbs.	16	1	980	1160
,, 15. *Maximum* produce of 9 plots with artificial mineral manures:— Superphosphate lime 350 lbs. Phosphate magnesia 168 lbs. Phosphate potass 150 lbs. Silicate potass 112 lbs.	17	3½	1096	1240
Mean of the 9 plots with artificial mineral manures	16	3½	1009	1155
Mean of 3 plots with mineral manures and 65 lbs. each of sulphate ammonia	21	0	1275	1423
Mean of 2 plots with mineral manures and 150 lbs. and 300 lbs. of rape-cake respectively	18	1½	1078	1201
Plot 18. With complex mineral manure, 65 lbs. of sulphate of ammonia, and 150 lbs. of rape-cake	22	3½	1368	1768

The indications of the table are seen to be most conclusive, as showing what was the character of the exhaustion which had been induced by the previous heavy cropping, and what, therefore, should be the peculiar nature of the supply in a rational system of manuring. If the exhaustion had been connected with a deficiency of mineral constituents, we might reasonably have expected that by some one at least of the nine mineral conditions—supplying in some cases an abundance of every mineral constituent which the plant could require—this deficiency would have been made up; but it was not so.

* It should be stated that the terms Superphosphate of Lime, Phosphate of Potass, Phosphate of Soda, and Phosphate of Magnesia, as used in this and the following Tables, and by which it is convenient to designate the manures, are not to be understood as representing the chemical substances bearing those names. They were formed by acting upon burnt bone-dust by means of sulphuric acid in the first instance, and in the cases of the alkaline salts and the magnesian one by neutralising the compound thus obtained by means of cheap preparations of the respective bases. The Silicate of Potass was manufactured at a glass-house by fusing equal parts of pearlash and sand—a transparent glass, slightly deliquescent in the air, was the result. It was ground to powder under edge-stones. The Sulphate and the Muriate of Ammonia were such as are usually sold for the purposes of manure, and it may be estimated that one hundredweight of them respectively is equal to 100 lbs. of the pure crystallized salt. The sulphuric acid used was of the specific gravity of about 1·7.

Thus, taking the column of bushels per acre as given in this summary, as our guide, it will be seen that whilst we have without manure only 16 bushels of dressed corn, we have by farm-yard manure 22 bushels. The *ashes* of farm-yard manure give, however, no increase whatever over the unmanured plot. Again, out of the 9 plots supplied with artificial mineral manures, we have in no case an increase of 2 bushels by this means; the produce of the average of the 9 being not quite 17 bushels. On the other hand, we see that the addition to some of these purely mineral manures of 65 lbs. of sulphate of ammonia—a very small dressing of that substance, and containing only about 14 lbs. of ammonia—has given us an average produce of 21 bushels. An insignificant addition of rape-cake too, to manures otherwise ineffective, has given us about 18½ bushels; and when, as in plot 18, we have added to the inefficient mineral manures 65 lbs. of ammoniacal salts, and a little rape-cake also, we have a produce greater than by the 14 tons of farm-yard manure.

The quantities of rape-cake used were small, and the increase attributable to it also small, but it nevertheless was much what we should expect when compared with that from the ammoniacal salts, if, as we believe is the case, the effect of rape-cake on *grain-crops* is due to the nitrogen it contains.

Indeed, the coincidence in the slight or non-effect throughout the mineral series on the one hand, and of the marked and nearly uniform result of the nitrogenous supply on the other, was most striking in the first year's experimental produce, and such as to lead us to give to nitrogenous manures in the second season even greater prominence than we had done to minerals in the previous one. This is in some respects, perhaps, to be regretted, as had we kept a series of plots for some years continuously under minerals alone, the evidence, though at present sufficiently conclusive, would have carried with it somewhat more of *systematic* proof.

In Table II. (see following page) we have given a few results selected from those obtained at the harvest of 1845, the second of the experimental series. By the table it is seen that we have, at the harvest of 1845, a produce of rather more than 23 bushels without manure of any kind, instead of only 16 as in 1844; and in like manner the farm-yard manure gives 32 bushels in 1845, and only 22 in 1844. We have shown in a former number of the Journal how clearly these differences can be traced to variations in the climatic character of the *season*, but this is not the point under consideration just now.

We assume, then, 23 bushels or thereabouts to be the standard produce of the soil and season, without manure, during this second experimental year; and as part of plot 5 (previously manured

TABLE II.

Harvest 1845. Selected Results. (See second section of diagram I., opposite p. 14.)

Description and Quantities of the Manures per Acre.	Dressed Corn per Acre, in Bushels and Pecks.		Total Corn per Acre, in lbs.	Straw per Acre, in lbs.
	bush.	pecks.	lbs.	lbs.
Section 1.				
Plot 3. No manure	23	0¾	1441	2712
,, 2. 14 tons of farm-yard manure . . .	32	0½	1967	3915
Section 2.				
,, 5*a*. No manure	22	2¼	1431	2684
,, 5*b*. Top-dressed with 252 lbs. of carbonate ammonia (dissolved), at 3 times, during the spring	26	3¾	1732	3599
Section 3.				
,, 9. {Sulphate of ammonia 168 lbs. / Muriate of ammonia 168 lbs.} top-dressed at once	33	1½	2131	4053
,, 10. {Sulphate of ammonia 168 lbs / Muriate of ammonia 168 lbs.} top-dressed at 4 times	31	3¼	1980	4266

with superphosphate of lime), and which is now, also, without manure, gives rather more than 22½ bushels of dressed corn, the correctness of the result of plot 3, the permanently unmanured plot, is thereby fully confirmed.

This plot No. 5, previously two-thirds of an acre, was, in this second year, divided into two equal portions; one of these ("plot 5*a*") being, as just said, unmanured, and the other ("plot 5*b*") having supplied to it in solution, by top-dressings during the spring, the *medicinal carbonate of ammonia*, at the rate of 250 lbs. per acre: and it is seen that we have, by this pure but highly volatile ammoniacal salt alone, the produce raised from 22¼ bushels to very nearly 27 bushels!

In the next section of the table are given the results of plots 9 and 10, the former of which had in the previous year been manured by superphosphate of lime and a small quantity of sulphate of ammonia, and the latter by superphosphate of lime and silicate of potass. To each of these plots 1½ cwt. of sulphate and 1½ cwt. of muriate of ammonia were now supplied. Upon plot 9 the whole of the manure was top-dressed, *at once*, early in the spring; but on plot 10 the salts were put on at four successive periods. The produce obtained by these salts of ammonia alone is 33 bushels and three-eighths, when sown all at once, and nearly 32 bushels when sown at four different times—quantities which amount to about 10 bushels per acre more than was obtained

without manure. In the case of No. 9, indeed, the produce exceeds by 1½ bushel that given by farm-yard manure, and in that of No. 10 it is all but identical with it. And if we take the weights of total corn, instead of the *measure* of the dressed corn, to which latter we chiefly refer, merely as a standard more conventionally understood, No. 10, by ammonia only, has given both more corn and more straw than the farm-yard manure, with all its minerals and carbonaceous substance.

Let us see whether this almost specific effect of nitrogen, in restoring, for the reproduction of corn, a corn-exhausted soil, is borne out by the results of succeeding years.

In relation to the third experimental year (harvest 1846), we have already given in a tabular form in our former article most of the results; but for want of time and space the attention of the reader was specially called to one or two of them only. We shall, therefore, on this occasion offer a few remarks on some of those not previously discussed; and we should have omitted all reference to the results obtained with the wheat manure of Professor Liebig, to which we have already called attention, had not the Professor, in the new edition of his 'Letters,' whilst fully admitting the failure of the manure—the composition of which, to use his own words when commenting upon it, "could be no secret, since every plant showed by its ashes the due proportion of the constituents essential to its growth" (page 482),—not expressed any doubt as to the principle involved in such a manure, but, on the other hand, implied that the failure was due to a yet imperfect knowledge of the mechanical form and chemical qualities required to be given to the necessary constituents in order to fit them for their reception and nutritive action on the plant, rather than to any fallacy in the theory which would recommend to practical agriculture the supply by artificial means of the constituents of the ashes of plants as manures.

We do not mean to say that Liebig's manure was not at fault as to its mechanical form and chemical qualities, and *from their failure* the same might, perhaps, be said of all the mineral mixtures employed in our experiments. We must be careful, however, not to rely upon an argument of this kind without sufficient ground, for it must be observed that in this way every negative result of experiment whatever might be held as showing nothing, and indeed that every positive one was equally little to be trusted; for it might be said that had we managed better, the one which is now negative might have been the most successful, and thus experiments of any kind would be at an end, and useless.

But to return to the experiments. The following table gives our selection of the results of the third season, 1846:—

TABLE III.

Harvest 1846. Selected Results. (See third section of diagram I., opposite p. 14.)

Description and Quantities of the Manures per Acre.	Dressed Corn per Acre, in Bushels and Pecks.		Total Corn per Acre, in lbs.	Straw per Acre, in lbs.
	bush.	pecks.	lbs.	lbs.
Section 1.				
Plot 3. No manure	17	3¾	1207	1513
,, 2. 14 tons of farm-yard manure . .	27	0¾	1826	2454
Section 2.				
,, 10*b*. No manure	17	2½	1216	1455
,, 10*a*. Sulphate of ammonia 224 lbs. . .	27	1½	1850	2244
Section 3.				
,, $5a^1$. Ash of 3 loads of wheat straw . .	19	0½	..	1541
,, $5a^2$. Ash of 3 loads of wheat straw, and top-dressed with 224 lbs. of sulphate of ammonia	27	0	..	2309
Section 4.				
,, 6*a*. Liebig's wheat manure 448 lbs. . .	20	1½	1400	1676
,, 6*b*. Liebig's wheat manure 448 lbs., with 112 lbs. each of sulphate and muriate of ammonia	29	0¾	1967	2571

At this third experimental harvest we have on the continuously unmanured plot, namely, No. 3, not quite 18 bushels of dressed corn, as the normal produce of the season; and by its side we have on plot 10*b*,—comprising one-half of the plot 10 of the previous years, and so highly manured by ammoniacal salts in 1845, but now unmanured,—rather more than 17½ bushels. The near approach, again, to identity of result from the two unmanured plots, at once gives confidence in the accuracy of the experiments, and shows us how effectually the preceding crop had, in a practical point of view, reduced the plots, previously so differently circumstanced both as to manure and produce, to something like an uniform standard as regards their grain-producing qualities. We take this opportunity of particularly calling attention to these coincidences in the amount of produce in the two unmanured plots of the different years, because it has been objected against our experiments, as already published, that confirmation was wanting as to the natural yield of soil and season.

Plot 2 has, as before, 14 tons of farm-yard manure, and the produce is 27¼ bushels, or between 9 and 10 bushels more than without manure of any kind.

On plot 10*a*, which in the previous year gave by ammoniacal

salts alone a produce equal to that of the farm-yard manure, we have again a similar result: for 2 cwts. of sulphate of ammonia has now given 1850 lbs. of total corn, instead of 1826 lbs., which is the produce on plot 2. The straw of the latter is, however, slightly heavier than that by the ammoniacal salt.

Again, plot 5*a*, which was in the previous season *unmanured*, was now subdivided: on one half of it (namely, 5*a*^{1}) we have the ashes of wheat-straw alone, by which there is an increase of rather more than 1 bushel per acre of dressed corn; on the other half (or 5*a*^{1}) we have, besides the straw ashes, 2 cwts. of sulphate of ammonia put on as a top-dressing: 2 cwts. of sulphate of ammonia have, in this case, only increased the produce beyond that of 5*a*^{1} by 7¼ bushels of corn and 768 lbs. of straw, instead of by 9⅝ bushels of corn and 789 lbs. of straw, which was the increase obtained by the same amount of ammoniacal salt on 10*a*, as compared with 10*b*. It will be observed, however, that in the former case the ammoniacal salts were top-dressed, but in the latter they were drilled at the time of sowing the seed; and it will be remembered that in 1845 the result was better *as to corn* on plot 9, where the salts were sown earlier, than on plot 10, where the top-dressing extended far into the spring. We have had several direct instances of this kind in our experience, and we would give it as a suggestion, in most cases applicable, that manures for wheat, and especially ammoniacal ones, should be applied before or at the time the seed is sown; for, although the apparent luxuriance of the crop is greater, and the produce of straw really heavier, by spring rather than autumn sowings of Peruvian guano and other ammoniacal manures, yet we believe that that of the *corn* will not be increased in an equivalent degree. Indeed, the success of the crop undoubtedly depends very materially on the progress of the underground growth during the winter months; and this again, other things being equal, upon the quantity of available nitrogenous constituents within the soil, without a liberal provision of which, the range of the fibrous feeders of the plant will not be such, as to take up the minerals which the soil is competent to supply, and in such quantity as will be required during the after progress of the plant for its healthy and favourable growth.

The next result to be noticed is that obtained on plot 6, now also divided into two equal portions designated respectively 6*a* and 6*b*. Plot No. 6 had for the crop of 1844 superphosphate of lime and the phosphate of magnesia manure, and for that of 1845 superphosphate of lime, rape-cake, and ammoniacal salts. For this, the third experimental season, it was devoted to the trial of the wheat manure manufactured under the sanction of Professor Liebig, and patented in this country.

Upon plot 6*a*, 4 cwts. per acre of the patent wheat-manure were

used, which gave 20½ bushels, or rather more than 2 bushe beyond the produce of the unmanured plot; but as the manu contained, besides the minerals peculiar to it, some nitrogeno compounds, giving off a very perceptible odour of ammonia, som at least, of the increase would be due to that substance. C plot 6*b*, however, the further addition of 1 cwt. each of sulpha and muriate of ammonia to this so-called "Mineral Manure gives a produce of 29½ bushels. In other words, the addition ammoniacal salt to Liebig's mineral manure has increased t produce by very nearly 9 bushels per acre beyond that of t mineral manure alone, whilst the increase obtained over t unmanured plot, by 14 tons of farm-yard manure, was on 9½ bushels!

If, then, the "mechanical form and chemical qualities" the so-called "Mineral Manure" were at fault, the sulphate ammonia has, at least, compensated for the defect; and ev supposing a mineral manure, founded on a knowledge of t composition of the ashes of the plant, be still the great desi ratum, the farmer may rest contented, meanwhile, that he has ammonia, supplied to him by Peruvian guano, by ammonia salts, and by other sources, so good a substitute.

In Table IV. are one or two of the results of the harvest 1847, which bear upon our question.

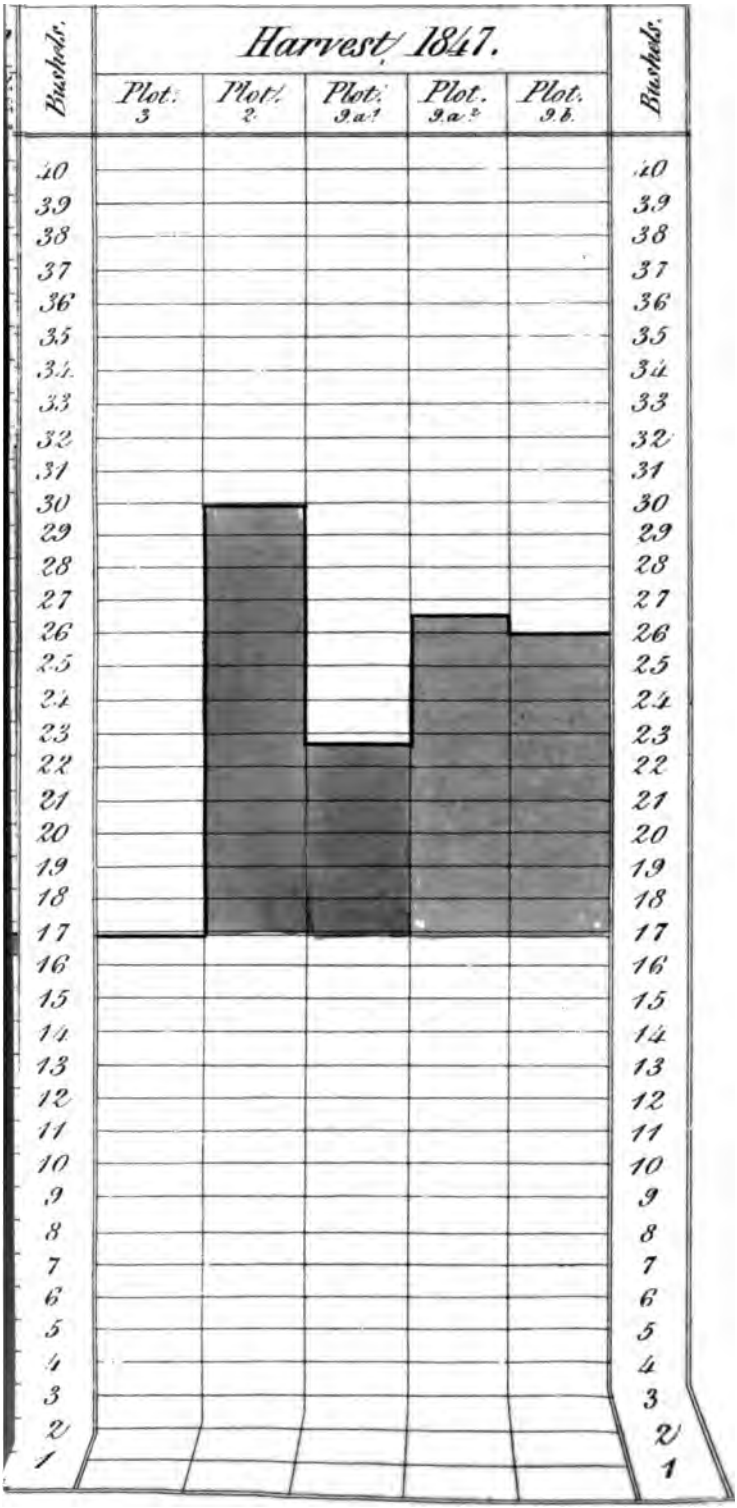
TABLE IV.

Harvest 1847. Selected Results. (See fourth section of diagram I. opposite p. 14.)

Description and Quantities of the Manures per Acre.	Dressed Corn per Acre, in Bushels and Pecks.		Total Corn per Acre, in lbs.	Stre per A in lb
	bush.	pecks.	lbs.	lbs.
Section 1.				
Plot 3. No manure	16	3½	1123	190
,, 2. 14 tons of farm-yard manure . . .	29	3½	1981	362
Section 2.				
,, 9a^1. 1 ton of Rice	22	3		
,, 9a^2. { Sulphate of ammonia 150 lbs. / Muriate of ammonia 150 lbs. } . .	26	2		
,, 9*b*. { Sulphate of ammonia 150 lbs. / Muriate of ammonia 150 lbs. } . .	26	0		

The produce of the continuously unmanured plot is now se to be almost 17 bushels of dressed corn, and that of the plot w farm-yard manure nearly 30 bushels.

Plots 9*a* and 9*b*, the former of which had in the previous s son 4 cwts. of rape-cake, and the latter 4 cwts. of rape-cake s


Harvest 1847.
Bushels.
Plot. 3
Plot. 2.
Plot. 3.a.1
Plot. 3.a.2
Plot. 3.b.
40
39
38
37
36
35
34
33
32
31
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5
4
3
2
1

2 cwts. of sulphate of ammonia, with no direct mineral manure in either case since the first season of 1844, were in this, the fourth season, set apart for the trial of some substance rich in *carbon* (but not so either in nitrogen or in mineral matter), by the side of pure nitrogenous supply. Thus one half of 9*a* (9*a*^{1}) was manured with *ground rice*, at the rate of 1 ton to the acre. The other half of 9*a* (9*a*^{4}) had 150 lbs. of sulphate and 150 lbs. of muriate of ammonia; as also had 9*b*. The effect of the 1 ton of rice is to give 22¾ bushels of dressed corn, or only 6 bushels more than the unmanured plot; whilst the ammoniacal salts of 9*a*^{2} and 9*b* gave respectively 26½ and 26 bushels. That is to say, with a difference of only half a bushel in the two cases with ammoniacal salts, an average is obtained of 9½ bushels more than on the unmanured plot.

It surely is needless to attempt further to justify, by the results of individual years, our assertion, that in practical agriculture nitrogenous manures are peculiarly adapted to the growth of wheat. We shall therefore conclude this part of our subject by directing attention to the history of a few of the plots throughout the entire series of years up to the present time, as compared with that of the unmanured plot during the same period.

The six next tables which follow (numbered V. to X. inclusive) give the results of 6 of the plots thus compared with the unmanured one; and in Table XI. we have the results of all those plots brought together in one view.

TABLE V.

Showing the Results of Plot 10*a* compared with those of the Unmanured Plot. (See first section of diagram II., opposite p. 28.)

Harvest.	Description of the Manures of Plot 10*a*.; the yield of which stands in the *second* column.	Section 1. Actual produce per Acre.						Section 2. Increase per Acre by Manure.		
		Dressed Corn, in Bushels and Pecks.		Total Corn, in lbs.		Straw, in lbs.				
		Plot 3. Unmanured.	Plot 10*a*.	Plot 3. Unmanured.	Plot 10*a*.	Plot 3. Unmanured	Plot 10*a*.	Dressed Corn, in Bushels and Pecks.	Total Corn, in lbs.	Straw, in lbs.
		bush. pks.	bush. pks.	lbs.	lbs.	lbs.	lbs.	bush. pks.	lbs.	lbs.
1844	Superphosphate of Lime 560 lbs., and Silicate of Potass 220 lbs.	16 0	16 3¾	923	1008	1120	1112	0 3¾	85	−8
1845	Sulphate of Ammonia 168 lbs., and Muriate of Ammonia 168 lbs., top-dressed at 4 times	23 0¾	31 3½	1441	1980	2712	4266	8 2½	539	1554
1846	Sulphate of Ammonia 224 lbs.	17 3¾	27 1½	1207	1850	1513	2244	9 1¾	643	731
1847	Sulphate of Ammonia 150 lbs., and Muriate of Ammonia 150 lbs.	16 3½	25 3	1123	1702	1902	2891	8 3½	579	989
1848	Sulphate of Ammonia 150 lbs., and Muriate of Ammonia 150 lbs.	14 3	19 1	952	1334	1712	2367	4 2	382	655
1849	Sulphate of Ammonia 200 lbs., and Muriate of Ammonia 200 lbs.	19 1	32 2	1227	2141	1614	2854	13 1	914	1240
1850	Sulphate of Ammonia 200 lbs., and Muriate of Ammonia 200 lbs.	15 3½	26 3½	1000	1721	1719	3089	11 0¼	721	1370
	Totals	123 3½	180 2	7873	11,736	12,292	18,823	56 2½	3863	6531
	Mean per annum . .	17 7¾	25 3¼	1125	1676	1756	2689	8 0½	552	933

Harvest.	Description of the Manures of Plot 10b.; the yield of which stands in the *second* column.	Actual produce per Acre.						Section 2. Increase per Acre by Manure.		
		Dressed Corn, in Bushels and Pecks.		Total Corn, in lbs.		Straw, in lbs.				
		Plot 3. Unmanured.	Plot 10b.	Plot 3. Unmanured.	Plot 10b.	Plot 3. Unmanured.	Plot 10b.	Dressed Corn, in Bushels and Pecks.	Total Corn, in lbs.	Straw, in lbs.
		bush. pks.	bush. pks.	lbs.	lbs.	lbs.	lbs.	bush. pks.	lbs	lbs.
1844	Superphosphate of Lime 560 lbs., and Silicate of Potass 220 lbs.	16 0	16 3¾	923	1008	1120	1112	0 3¾	85	−8
1845	Sulphate of Ammonia 168 lbs., and Muriate of Ammonia 168 lbs., top-dressed at 4 times	23 0¼	31 3¼	1441	1980	2712	4266	8 2½	539	1554
1846	No Manure	17 3¾	17 2½	1207	1216	1513	1455	−0 1¼	9	−58
1847	Sulphate of Ammonia 150 lbs., and Muriate of Ammonia 150 lbs.	16 3½	25 2¾	1123	1705	1902	2874	8 3¼	582	972
1848	Pearlash 300 lbs., Soda-ash 200 lbs., and Sulphate of Magnesia 100 lbs., Calcined Bone-dust 200 lbs., Sulphuric Acid 150 lbs., and 150 lbs. each of Sulphate and Muriate of Ammonia	14 3	25 0¼	952	1604	1712	2926	10 1¼	652	1214
1849	Sulphate of Ammonia 200 lbs., and Muriate of Ammonia 200 lbs.	19 1	32 2¾	1227	2156	1614	2964	13 1¾	929	1350
1850	Pearlash 300 lbs., Soda-ash 200 lbs., and Sulphate of Magnesia 100 lbs., Bone Ash 200 lbs., and Sulphuric Acid 150 lbs.	15 3¼	17 3¾	1000	1171	1719	1949	2 0½	171	104
	Totals	123 3¼	167 3	7873	10,840	12,292	17,546	43 3¾	2967	5128
	Mean per Annum . .	17 2¾	23 3¾	1125	1548	1756	2507	6 1	424	733

C

Table VII.

Showing the Results of Plot 18*a* compared with those of the Unmanured Plot. (See third section of diagram II., opposite p. 28.)

Harvest.	Description of the Manures of Plot 18*a*.; the yield of which stands in the *second* column.	Section 1. Actual produce per Acre.						Section 2. Increase per Acre by Manure.		
		Dressed Corn, in Bushels and Pecks.		Total Corn, in lbs.		Straw, in lbs.		Dressed Corn, in Bushels and Pecks.	Total Corn, in lbs.	Straw, in lbs.
		Plot 3. Unmanured.	Plot 18*a*.	Plot 3. Unmanured.	Plot 18*a*.	Plot 3. Unmanured.	Plot 18*a*.			
		bush. pks.	bush. pks.	lbs.	lbs.	lbs.	lbs.	bush. pks.	lbs.	lbs.
1844	350 lbs. Superphosphate of Lime, 84 lbs. Phosphate of Magnesia, 65 lbs. of Phosphate of Soda, 75 lbs. Phosphate of Potass, 112 lbs. Silicate of Potass, 65 lbs. Sulphate of Ammonia, 154 lbs. of Rape Cake	16 0	22 3½	923	1368	1120	1768	6 3½	445	648
1845	336 lbs. Superphosphate of Lime, and 112 lbs. each of Sulphate and Muriate of Ammonia . . .	23 0¾	33 0½	1441	2048	2712	3819	9 3½	607	1107
1846	224 lbs. Calcined Bone-dust, 224 lbs. Sulphuric Acid, 60 lbs. Soda Ash, 67 lbs. Pearlash, and 84 lbs. Magnesian Limestone; and 112 lbs. each of Sulphate and Muriate of Ammonia . . .	17 3¾	31 0	1207	2048	1513	2838	15 0½	841	1325
1847	100 lbs. Calcined Bone-dust, 100 lbs. Sulphuric Acid, and 150 lbs. each of Sulphate and Muriate of Ammonia	16 3½	32 0¾	1123	2160	1902	3852	15 1½	1037	1950
1848	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs. Sulphate of Magnesia, 200 lbs. Calcined Bone dust, 150 lbs. Sulphuric Acid, and 150 lbs. each of Sulphate and Muriate of Ammonia	14 3	26 3	952	1734	1712	2935	12 0	782	1223
1849	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs. Sulphate of Magnesia, 200 lbs. Calcined Bone-dust, 150 lbs. Sulphuric Acid, and 200 lbs. each of Sulphate and Muriate of Ammonia	19 1	32 1½	1227	2162	1614	3592	13 0½	935	1978
1850	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs. Sulphate of Magnesia, 200 lbs. Bone-ash, 150 lbs. Sulphuric Acid, and 200 lbs. each of Sulphate and Muriate of Ammonia	15 3¼	29 3	1000	1934	1719	3927	13 3¾	934	1208

TABLE VIII.

Showing the Results of Plot 18b compared with those of the Unmanured Plot. (See fourth section of diagram II., opposite p. 28.)

Harvest.	Description of the Manures of Plot 18b.; the yield of which stands in the *second* column.	Section 1. Actual produce per Acre.						Section 2. Increase per Acre by Manure.		
		Dressed Corn, in Bushels and Pecks.		Total Corn, in lbs.		Straw, in lbs.		Dressed Corn, in Bushels and Pecks.	Total Corn, in lbs.	Straw, in lbs.
		Plot 3. Unmanured.	Plot 18b.	Plot 3. Unmanured.	Plot 18b.	Plot 3. Unmanured.	Plot 18b.			
		bush. pks.	bush. pks.	lbs.	lbs.	lbs.	lbs.	bush. pks.	lbs.	lbs.
1844	350 lbs. Superphosphate of Lime, 84 lbs. Phosphate of Magnesia, 65 lbs. Phosphate of Soda, 75 lbs. Phosphate of Potass, 65 lbs. Sulphate of Ammonia, 112 lbs. Silicate of Potass, 154 lbs. of Rape-cake	16 0	22 3½	923	1368	1120	1768	6 3½	445	648
1845	336 lbs. Superphosphate of Lime, 112 lbs. each of Sulphate and Muriate of Ammonia	23 0½	33 0½	1441	2048	2712	3819	9 3½	607	1107
1846	224 lbs Calcined Bone-dust, 224 lbs. Sulphuric Acid, 60 lbs. Soda Ash. 67 lbs. Pearlash, and 84 lbs. Magnesian Limestone	17 3½	21 1	1207	1474	1513	1893	3 1½	267	380
1847	100 lbs. Calcined Bone-dust, 100 lbs. Sulphuric Acid, and 150 lbs. each of Sulphate and Muriate of Ammonia	16 3½	29 1½	1123	2029	1902	4164	12 2	906	2262
1848	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs. Sulphate of Magnesia, 200 lbs. Calcined Bone-dust, 150 lbs. Sulphuric Acid, and 150 lbs. each of Sulphate and Muriate of Ammonia	14 3	26 2½	952	1804	1712	3056	11 3½	852	1344
1849	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs Sulphate of Magnesia, 200 lbs. Calcined Bone-dust, 150 lbs. Sulphuric Acid, and 200 lbs each of Sulphate and Muriate of Ammonia	19 1	33 2½	1227	2242	1614	3778	14 1½	1015	2164
1850	300 lbs. Pearlash, 200 lbs. Soda Ash, 100 lbs. Sulphate of Magnesia, 200 lbs. Bone-ash, 150 lbs. Sulphuric Acid, and 200 lbs. each of Sulphate and Muriate of Ammonia	15 3½	28 2½	1000	1845	1719	3843	12 3½	845	2124
	Totals	123 3½	195 1½	7873	12,810	12,293	22,321	71 2½	4937	10,029
	Mean per Annum	17 2½	27 3½	1125	1830	1756	3189	10 1	705	1433

TABLE XI.

SUMMARY.—Showing the Results of Plots 10*a* and 10*b*, 18*a* and 18*b*, 17*b*, and 2, with those of the Unmanured Plot.

Harvests	Section 1. Dressed Corn per Acre, in Bushels and Peeks.														Section 2. Total Corn per Acre, in lbs.							Section 3. Total Straw per Acre, in lbs.						
	Plot 3. Unmanured		Plot 10*a*.		Plot 10*b*.		Plot 18*a*.		Plot 18*b*.		Plot 17*b*.		Plot 2.		Plot 3. Unmanured	Plot 10*a*.	Plot 10*b*.	Plot 18*a*.	Plot 18*b*.	Plot 17*b*.	Plot 2.	Plot 3. Unmanured	Plot 10*a*.	Plot 10*b*.	Plot 18*a*.	Plot 18*b*.	Plot 17*b*.	Plot 2.
	bh.	pk.	bh.	pk.	bh.	pk	bh.	pk	bh.	pk.	bh.	pk.	bh.	pk.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1844	16	0	16	3½	16	3½	22	3½	22	3½	20	2½	22	0	923	1008	1008	1368	1368	1240	1267	1120	1112	1182	1768	1768	1429	1476
1845	23	0½	31	3½	31	3½	33	0½	33	0½	32	0½	32	0½	1441	1980	1980	2048	2048	2093	1967	2712	4266	4266	3819	3819	3826	3915
1846	17	3½	27	1½	17	2½	31	0	21	1	30	2	27	0½	1207	1850	1216	2048	1474	2034	1826	1513	2244	1455	2838	1893	2784	2454
1847	16	3½	25	3	25	2½	32	0½	29	1½	35	1½	29	3½	1123	1702	1705	2160	2029	2314	1981	1902	2891	2874	3852	4164	4261	3628
1848	14	3	19	1	25	0½	26	3	26	2½	28	3½	25	2½	952	1334	1604	1734	1804	1946	1705	1712	2367	2926	2935	3056	3324	3041
1849	19	1	33	2	32	2½	32	1½	33	2½	33	1½	30	3	1227	2141	2156	2162	2242	2257	2053	1614	2654	2964	3592	3778	3858	3005
1850	15	3½	26	3½	17	3½	29	3	28	2½	29	2½	28	2½	1000	1721	1171	1934	1845	1960	1861	1719	3089	1823	3927	3843	4034	3245
Totals	123	3½	180	2	167	3	207	3½	195	1½	210	2	196	1½	7873	11,736	10,840	13,454	12,810	13,844	12,669	12,292	18,823	17,420	22,731	22,321	23,529	20,764
Mean..	17	2½	25	3½	23	3½	29	2½	27	3½	30	0½	28	0½	1125	1776	1548	1922	1830	1978	1809	1756	2689	2489	3247	3189	3361	2966

In Table V. we have compared together the produce of the unmanured plot with that of Plot 10*a*, which, excepting in 1844, when superphosphate of lime and silicate of potass were used (giving, however, less than one bushel of increase), was manured in every succeeding season by ammoniacal salts alone.

It is a remarkable fact that from Plot 3 (the unmanured one), of this previously unusually corn-exhausted soil, we have carried from the land seven successive crops of wheat grain, and of straw, without any manure whatever; and that under this treatment there are, at present, no signs of diminished fertility; for the average of the seven seasons collectively is about 17½ bushels of dressed corn, and about 16 cwts. of straw, or more than was obtained in the first experimental year. Indeed, there is little doubt that upon a soil of any given quality the produce will only vary with the character of the climate and the variations of the seasons, which must materially affect the amount of *ammonia* available from natural sources; and upon this again depends the assimilation of other constituents, which in the case of our experiments were proved to have existed in ample *relative* quantity within the reach of the plant. Thus, the results of Plot 10*a*, as seen in the 2nd column of the table, are alone sufficient to show that, whatever the deprivation by the previous cropping, the soil still contained, *relatively to the ammonia available from natural sources*, an EXCESS of the necessary mineral constituents. We shall presently show that this must be the condition of most if not all cultivated land, where *grain* and *meat* constitute—as they do, as the rule, in Great Britain—almost the exclusive exports from the farm; the straw of the grain and the excrements of the animals fed upon the farm, finding their way into the home manures, and eventually back again to the fields from whence they came.

But we must not be understood to say that all soils will yield continuously 17½ bushels of grain and 16 cwts. of straw per acre, without manure; on the contrary, we know full well that they will not, and that what are termed light soils, but which, under high cultivation, give good crops of wheat, would give but a small proportion of this quantity. That the heavier ones do possess a native fertility beyond what might at first sight be supposed, there can be little doubt; were it not so, we should find it difficult to explain how those who sell off their land almost all its produce without return, are enabled to live and pay their rent. But what we say is, that by the ordinary methods of practical agriculture, by which any soils are made to yield a fair produce of grain and meat only, for sale, their characteristic exhaustion, as grain producers, will be that of NITROGEN; and that the mineral constituents, will, under this course, RELATIVELY TO NITROGEN, be in excess. *To* this point, however, we shall recur further on.

But to return to the Table (V.);—a glance will show that in *every* season the produce was greatly increased by ammoniacal salts only; and in the last two years even, when the amount of ammonia supplied was increased, so also was there a greater increase of produce obtained than in previous years; and this, notwithstanding there had been taken from the land in the previous rotation a heavy amount of minerals without return, and in the first five experimental crops the minerals, both of corn and of straw, of larger crops than are the average of the county under the ordinary system of rotation and home manuring.

The comparison afforded in Table VI. is very instructive. It gives the results of Plot 10*b*, by the side of the unmanured plot. The manuring of this Plot 10*b* was, it will be remembered, in 1844 precisely the same as that for Plot 10*a*, last under consideration; but in the succeeding years a different method of treatment was adopted. In this case, instead of giving year after year ammoniacal salts, these have been alternated with no manure, with minerals alone, and with minerals combined with ammoniacal salts, in order to ascertain how far the characteristic result of each of the conditions, thus successively provided, would in each case be developed, independently of the immediately preceding supply.

In the first year, the mineral manure gives less than one bushel increase;—in the second, ammoniacal salts give 8¾ bushels increase;—in the third season, after a heavy dressing by ammonia, and a heavy produce, the cessation of manuring reduces the produce to a trifle below that of the unmanured plot;—in the fourth year, ammoniacal salt alone increases the produce by *one half*;—in the fifth, a complex mineral manure, supplying nearly every mineral constituent of the crop in excess, and this combined with ammonia, gives an acreage produce even rather less than was obtained in the previous year without the minerals, and the *proportion of increase* over the unmanured plot is very little greater. In the sixth season we have, with a larger supply of nitrogen than usual, namely, with 200 lbs. of sulphate and 200 lbs. of muriate of ammonia per acre, an increase of 13½ bushels, or more than two-thirds over the unmanured plot. And in the seventh and last completed experimental season, this very heavy dressing of nitrogen is succeeded by a very liberal supply of minerals, which minerals however raise the produce only two bushels above the yield of the unmanured plot. Nothing can be more striking and conclusive than the evidence afforded by the fluctuations in the produce of this Plot 10*b*, as showing that it would be much nearer the truth to say that the crop has risen and fallen in proportion to the diminution or increase of the *ammonia* supplied to it in manure, than of the mineral substances, as would be

assumed according to the theory of Professor Liebig. It is seen, too, that it is only in the later seasons that the available minerals have appeared to be in defect, in relation to the nitrogenous supply.

That the mineral constituents are indeed becoming deficient in several of the plots of our experimental fields, we have in our collective results, as well on turnips and beans as on wheat, abundant evidence; and as the circumstances under which this point has actually been arrived at, are well understood, we are the better able to speak with confidence as to the non-exhaustion of them in other cases. Of this we shall on some future occasion speak much more in detail, when we are able to bring forward more of the experimental facts relating to it than we can do in a mere outline of this kind. But the plots to which we shall now refer will afford some illustration of it.

We have seen, then, that on Plot 10*a* there has been in every year since the first experimental one a large amount of ammoniacal salts, but without mineral supply; and that by this means we have in every year obtained a considerable amount of produce beyond that without manure. In Plots 18*a*, 18*b*, and 17*b*, on the other hand, we have *in every year mineral supply;* and in 1846, and ever since, this has been the same for these three plots, and always very liberal in nearly all the constituents required by the crop,—and in addition to this very liberal mineral provision, we have in each year, on one or more of these plots, exactly the same ammoniacal supply as in Plot 10 *a*, which had no mineral manure, so that we are thus enabled to show at what point the mineral supplies of the native soil were, in 10 *a*, deficient, in relation to the quantity of ammonia artificially applied to it. For the particulars of the manures of Plots 18*a*, 18*b*, and 17*b*, we must refer the reader to Tables 7, 8, 9, respectively, but the comparisons of produce to which we wish now to call attention will be better seen in the summary table, No. 11.

Thus, taking the cases of exactly similar ammoniacal supply, but in Plot 10*a* *without* mineral, and in the plot compared with it, *with* minerals, we have in 1845,—

On Plot 10*a*, 31¼ bushels of dressed corn and 4266 lbs. of straw, by 168 lbs. each, of sulphate and muriate of ammonia.

On Plot 18, 33 bushels of dressed corn and 3819 lbs. of straw, with only 112 lbs. each, of the ammoniacal salts, but *with* mineral manure.

In 1846, with equal ammoniacal supply in the two cases, we have,—

On Plot 10*a*, 27½ bushels of dressed corn and 2244 lbs. of straw, *without* minerals.

On Plot 17*b*, 30½ bushels of dressed corn and 2784 lbs. of straw, *with* minerals.

In 1847, with ammoniacal supply only, we have,—

On Plot 10*a*, 25¾ bushels of dressed corn and 2891 lbs. of straw.
On Plot 18*a*, 32¼ bushels of dressed corn and 3852 lbs. of straw, *with* minerals added.

In 1848, we have,—

On Plot 10*a*,* 19½ bushels of dressed corn and 2367 lbs. of straw.
On Plot 18*a*, 26¾ do. do. and 2935 lbs. do.

In 1849, we have,—

On Plot 10*a*, 32½ bushels of dressed corn and 2854 lbs. of straw.
On Plot 18*a*, 32¼ do. do. and 3592 lbs. do.
On Plot 17*b*, 33¾ do. do. and 3858 lbs. do.
with minerals added to the two latter plots.

In 1850, again with ammoniacal salts only, we have,—

On Plot 10*a*, 27 bushels of dressed corn and 3089 lbs. of straw.

And the minerals and ammonia give—

On Plot 18*a*, 29¾ bushels of dressed corn and 3927 lbs. of straw.
On Plot 17*b*, 29½ do. do. and 4034 lbs. do.

Thus it appears, then, that although Plot 10*a*, with ammoniacal salts only, has given every year a considerable increase beyond that of the unmanured plot, yet the ammoniacal salts thus supplied were evidently much in excess over the minerals available within the soil; for in every case when minerals have been *also* liberally supplied, we have in corn, straw, or both, a considerably larger increase still. In 1849, indeed, the excessively mineral-exhausted plot (10*a*) gives about the same quantity of corn as those which had always a liberal provision of mineral constituents. The straw, however, is deficient.

The effect of mineral manures for the growth of wheat is then, in these cases, clearly shown:—but what are the circumstances under which this result is obtained? It is only when, after taking from the land the whole produce of a rotation without return, we provide *ammoniacal salts alone*, in such quantity as to yield crops year after year larger than the average obtained in the county under the ordinary course of rotation and home manuring; and the produce thus obtained by ammoniacal salts only, was very nearly equal to that resulting from an annual supply of 14 tons of farm-yard manure. We by no means suppose, however, that if some cheap source of ammonia were discovered, we might with

* The produce of this plot being so small, we had been disposed to suspect that some mistake had arisen either during the harvest or at the time of threshing. It was however observed that the crop in this season was particularly irregular and sickly where there was a deficiency of minerals; but as the produce of this plot (10*a*) was at the following harvest (1849) considerably more than we should have anticipated, we are disposed to believe that the result as stated for 1848 is probably correct, and that the high rate of increase by ammoniacal salts alone, in 1849, was partly due to the *non*-exhaustion by the previous crop.

impunity continuously exhaust our soils in the growth of corn by its means; but, on the contrary, fully admit that under such a course our mineral supply would soon become deficient. This is not the condition of British agriculture, and it is not for *such* circumstances, therefore, that we have at present to provide.

But to recur to the summary table. We see that notwithstanding in the two cases there was an equal and very liberal supply of minerals in 18*a* and 18*b*, we have with the cessation of ammoniacal supply in the latter, in 1846, a produce 10 bushels less than in the former, where the ammoniacal salts were continued. The produce of 18*b*. indeed, with the minerals only, is 3¼ bushels of corn and about 380 lbs. of straw more in 1846 than on the unmanured plot; but this exhaustion, by means of a liberal provision of minerals, seems to have been not without its effect upon the succeeding crop; for although, in 1847, Plots 18*a* and 18*b* are equal, both in mineral and ammoniacal manure, we have in the latter—which we have just seen gave 3 bushels increase under mineral only, in 1846—3 bushels *less* in 1847 than 18*a*. The straw, however, of 18*b* is about 300 lbs. heavier than that of 18*a*.

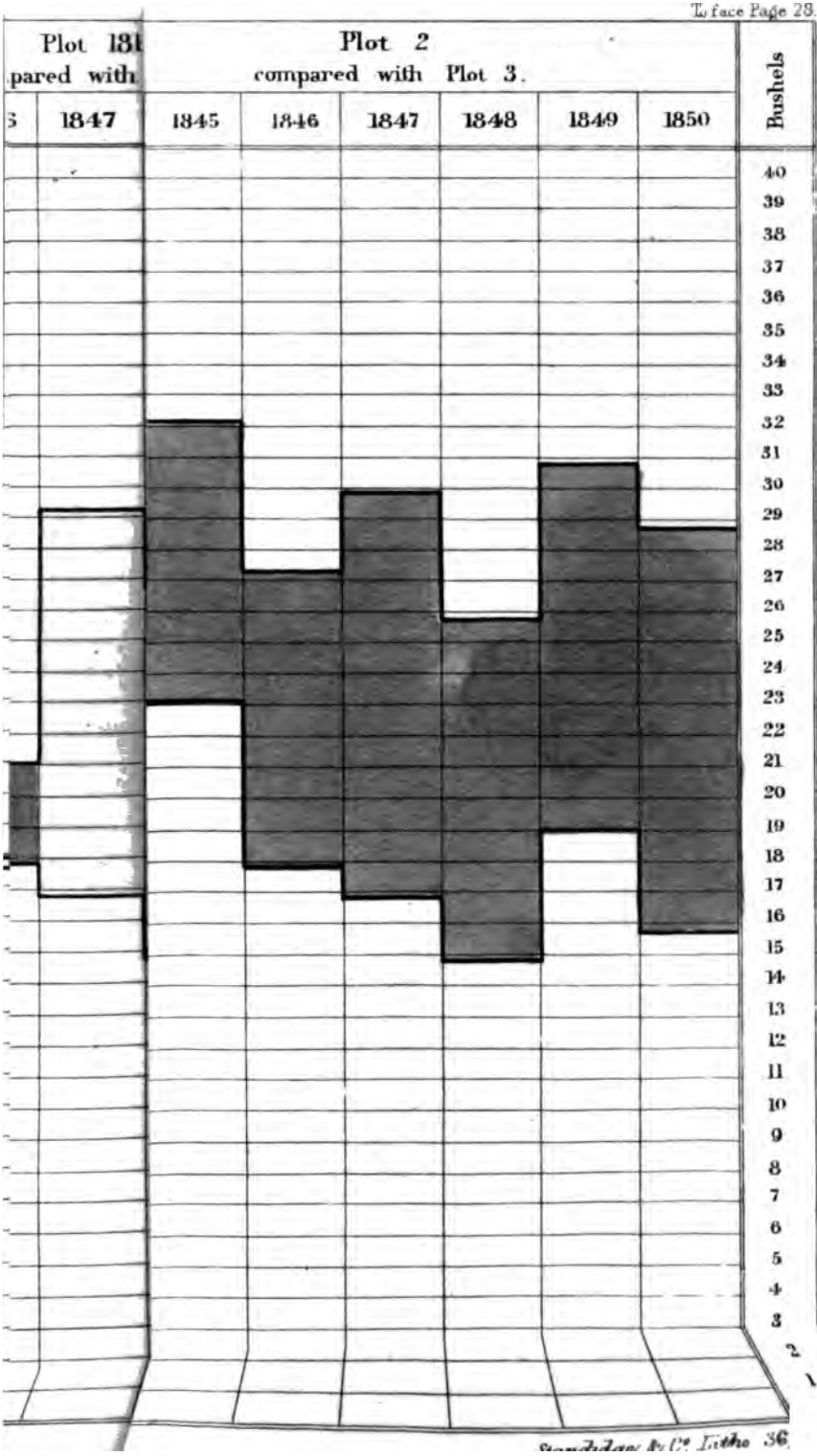
We may here observe that the production of straw, as well as that of grain, would seem to be intimately connected with the expenditure of nitrogen derived through the roots of the plant, and had we time to consider the question more fully on this occasion, we should not have dwelt so exclusively on the production of corn alone as we have done. We may, however, remark, that the production of a heavy crop of straw in a wet season is probably, from the cause alluded to, a very dearly purchased produce.

We have already said that, excepting in the first two seasons, the mineral manures of 17*b* were exactly the same as those of 18*a* and 18*b*, and although we have seen that the minerals of these plots have rendered the ammoniacal supply more effective than it was on 10*a* without the minerals, yet we observe that when, in 1847 and 1848, we give to 17*b* an *additional* quantity of ammoniacal salt, the produce is increased beyond that of 18*a* and 18*b*. Thus we have in 1847, with an increased amount of ammoniacal salt on 17*b*, 3¼ bushels more dressed corn and about 400 lbs. more straw than on 18*a* with its equal supply of minerals: and again, we have in 1848, on 17*b*, two bushels more dressed corn and 400 lbs. more straw than on 18*a*. It is clear then that the minerals supplied, which have been throughout much more than equivalent to those taken off in the increased produce, were only available so long as there was a liberal provision of nitrogen *in the soil*; and that when this artificially supplied nitrogen was exhausted, the minerals remained inactive and useless. We have, then, in the very cases where minerals gave an increased produce,

in the well-defined limit to their action which is indicated, further proof of the necessity of an artificial supply of nitrogen *in the soil* for the increased production of corn, and the incapability of mineral supply to yield any increase, excepting when nitrogen is thus provided.

Turning now to Table X., we find that the 98 tons of farm-yard manure which have been supplied during the last seven years have only given an increase of 73 bushels of dressed corn and 3 tons 15 cwts. of straw over the unmanured plot. This is equivalent to only ¾ of a bushel of corn and ¾ of a cwt. of straw for every ton of farm-yard manure supplied! Farm-yard manure is, however, a very variable compound; its composition being dependent upon the amount and quality of the food consumed by the animals which have produced it. According to the mean of several direct experiments upon very rich box-manure, a ton of it, in round numbers, is composed of 14½ cwts. of water, and 5½ cwts. of dry substance, the latter of which contains a large quantity of mineral matter and nitrogen equal to about 20 lbs. of ammonia; on the other hand, a ton of manure composed merely of straw wetted to the same degree, with of course the same amount of dry substance, only gives nitrogen equal to about 5 lbs. of ammonia, and probably much less than half of the more important minerals of the rich box-manure. The farm-yard manure carried out of our yards, as to nitrogen, will generally have a composition intermediate between these two extremes; and we may at any rate assume that that which we employed would contain about 5 cwts. of dry substance, of which the dry organic matter, rich in carbon, would be three or four times as great as, and the minerals also much in excess of, that required by the increase of corn and straw which we have seen to be obtained by their use. It is evident therefore that there must have been a great expenditure of non-nitrogenous organic substance, and of mineral matter, without effect; and we conceive that the increase obtained was much more intimately connected with the amount of nitrogen contained in the manure supplied. This view, indeed, would appear to be beyond doubt when we consider that the application of ammoniacal salts alone, during the last six years, as in plot 10*a*, has given an average increase within one bushel of that which has been obtained by the use of farm-yard manure.

Neither *mineral manures* nor *carbon* then, are indicated by our experiments as the special or direct manures for the growth of wheat. Not so, however, with the turnip, for the successful cultivation of which a liberal supply within the soil of carbonaceous substance and phosphates is found to be important. We have here then a remarkable contrast—for if in practice the Wheat plant be supplied with a sufficient amount of nitrogen,


Plot 1st
pared with
Plot 2
compared with Plot 3.
3
1847
1845
1846
1847
1848
1849
1850
Bushels
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

ɔt likely to be deficient in carbon or in mineral matter; he Turnip, on the other hand, will not be provided with e quantity of carbon independently of a coincident and ıtly sufficient supply of nitrogen. And it is in this ɜion into useful food for stock by the Root crop of the aceous matter of our straw, which, after it has served :r, would, beyond this, be a comparatively useless refuse grain crops, that phosphoric acid is found to be a very agent; whilst of the nitrogen stored up in the growth root crop, a much larger proportion than of the carbon ıs in the excrements of the animals, and serves in its turn : growth of the succeeding cereal grain: and hence is seen ual reliance between these two important crops of rotation. ɔ the influence of phosphoric acid upon the turnip crop we :ecur again presently.

t there is another point in connexion with the great demand by the wheat plant upon nitrogen supplied to the soil, to ı we wish to draw particular attention.

us, among from two to three hundred experiments with ɔniacal manures, we have in no single instance recovered in ıcrease the amount of nitrogen provided in the manure; his fact is perfectly consistent with the amounts of produce l, in the experience of the farmer, to be obtained by the use eruvian guano and other nitrogenous manures. Part of this t is doubtless due to the limited range of the roots of the t in relation to the distribution of the manure in the soil; much of it is materially dependent on a definite expenditure, speak, of nitrogen, which is taken up by the roots of the t and given off by its leaves to the atmosphere in the exercise ıe functional actions of its growth.

'e Saussure, Daubeny, and Draper have found that nitro- was really thus given off during the growth of certain plants; n a practical point of view the question still arises whether is uniform with all the different plants which enter into a ion.

relation to this subject we have ourselves, during the last years, undertaken a series of experiments, in the hope of ɜr or later elucidating this truly interesting and important ɜct. We cannot here enter into a consideration of the results h have been thus obtained, but we may briefly indicate a able conclusion to which the experiments would seem to lead, esults of a preliminary series of which have already been ished in the Journal of the Horticultural Society, for January '. Thus we have found, that whilst for a given quantity of r passed through the plant during its growth the amount of nitrogenous substances fixed in it is, within somewhat narrow

limits, identical; that of the *nitrogenous* proximates fixed is, on the other hand, about *twice* as great in the Leguminosæ as in the Graminaceæ. This fact, too, perfectly coincides with the results of our experiments in the field, with wheat and beans respectively, which show that under the same circumstances of growth, as to manure, &c., and in the same season, the *acreage* yield of nitrogen is twice or thrice as great in beans as in wheat. It cannot be supposed, however, that with the larger amount of nitrogen harvested in the leguminous crop the soil would be proportionally exhausted of it, for common practice teaches that, other things being equal, wheat, which is especially dependent on the supply of nitrogen in the soil, would give a larger produce after a bean than after a wheat crop.

Here then it would appear that there is evidence of a superior power in the leguminous, as compared with the graminaceous plants, of obtaining their nitrogen from the atmosphere rather than from the soil; or it may be supposed that the expenditure of it during the growth of the plant is greater in the one case than in the other.

In support of the view that leguminous plants do possess a superior power of reliance upon the atmosphere for their nitrogen, and, indeed, that it is to this property that they materially owe their efficacy in rotation with grain, we may refer to the admirable investigations into the Chemistry of Agriculture of M. Boussingault. His experiments, however, have not received the attention which they merit from the agriculturists of this country; probably on account of the small amounts of produce which he obtained. But it must be remembered that his investigation had for its object to explain the practices of agriculture as he found them in his own locality, before attempting to deviate from its established rules. M. Boussingault states the rotation usually adopted at Bechelbronn, and throughout the greater part of Alsace, to be as follows:—

"Potatoes or beet-root,"
"Wheat,"
"Clover,"
"Wheat;"

and that the average of wheat so obtained is, after potatoes 19½ bushels, after beet-root 17 bushels, and after clover 24 bushels. Now we find by reference to his table that the first crop of wheat, grain, and straw removed 17 lbs. of phosphoric acid and 24 lbs. of potash and soda; the following clover crop, 18 lbs. of phosphoric acid and 77 lbs. of potash and soda; and after this removal of alkalies and phosphates by the clover, a *larger* crop of wheat is obtained. Surely it would seem impossible to reconcile

s result with a theory which supposes the produce of wheat to
e and fall with the quantity of minerals available within the
l. If, however, we admit that the first crop of wheat could
t take up the mineral matters existing in the soil for want of
rogenous supply, and that the clover crop, not being so de-
ndent upon *supplied* nitrogen, was able to take up the minerals
uired for its growth, and that it moreover left in the soil,
ficient ammonia, or its equivalent of nitrogen in some form, to
e the *increased* crop of wheat, we have a much more consistent
d probable solution of the results. There is little doubt that
. Boussingault could have increased his produce of wheat by
ans of ammoniacal salts: whether he could have done so
nomically is another question, depending of course upon the
ative prices of grain and ammonia.

In our paper upon the growth of wheat, published in the
urnal of the Royal Agricultural Society in 1847, we have
empted an estimate of the probable amount of nitrogen
uired to obtain a given amount of it in the increased produce.
e there provisionally assumed that 5 lbs. of ammonia were
uired to produce an increase of one bushel of corn and its
uivalent of straw. We do not intend to enter fully into the
estion of the accuracy of this estimate on the present occasion,
t we may observe in passing, that among the plots the history
which we have given in the foregoing pages down to the last
rvest, there is not one, even under the best conditions as to
ificial mineral supply, where the ammonia, on the average of
sons, has given an increase equal to that supposed in our
imate. And even supposing that the farm-yard manure em-
yed in our experiments contained no more nitrogen than we
ve stated would have been provided in merely wetted straw, we
ve not obtained by its means as much as a bushel of corn and
equivalent of straw for each 5 lbs. of ammonia thus supplied
the manure. It may be said, perhaps, that the circumstances
experiments wherein wheat has been grown for several years
ccessively on the same land, are very artificial; but such is the
sult which they have yielded, and it is at any rate worthy of the
rious attention of the reader. In some cases of our experi-
nts, however, which are in no degree less artificial, a slightly
tter result has been obtained. But to this point we shall recur
some future occasion.

Without further inquiring then, into the correctness of our
timate, it would seem that a loss of this kind during the growth
the plant is a fact which is sufficiently substantiated, at once by
e practical experience of the farmer, and by experiments of an
dependent kind relating to it. And, let it once be recognised,
agricultural science, that there is a definite expenditure or

consumption of the nitrogenous bodies derived through the roots, connected with the fixation and elaboration of certain constituents of plants, and that this is greater or less according to the sources or the exact composition or state of elaboration of the products, and an important step will be gained towards a clearer conception of the principles involved in the alternation in a course of cropping, of plants of varying products and habits of growth. The fallacy, too, of the theory which would supply to plants a manure, founded on a knowledge of the percentage composition alone, whether of their ashes or of their organic substance, will at once be obvious. Nay, the converse of the axiom herein implied is more nearly true, at least in some important cases; for, as we have elsewhere asserted, with regard to the Wheat and Bean plants for example, the former, that is the Wheat, as compared with the latter, is characterized by a low percentage of nitrogen and a relatively high percentage of carbon; but all experience and the tendency of all our results is to show, that the low nitrogenized Wheat crop requires for its luxuriant growth an abundant supply of *nitrogen* by *manure*, and that with this it is *practically* independent of *supplied* carbon; whilst the highly nitrogenous Leguminous plant is, other things being equal, by no means strikingly and characteristically benefited by nitrogenous manures. Were it otherwise, where would be the subserviency of the leguminous plants grown in rotation with grain? We had, indeed, at one time supposed that *clover* was greatly dependent on an artificial provision of nitrogen, but this view is not favoured by further investigation; whilst with it, as well as with those leguminous plants valued in agriculture for their seeds, which are known practically to occupy a peculiar sphere when grown in alternation with the cereal grains, a *mineral*, and especially an *alkaline* manure, seems to be more prominently indicated. Indeed, it is to the *fallow crops* generally, or those which are grown in alternation with grain, that direct mineral manures are of essential service in enabling them to accumulate stores from the atmosphere; and in *this sense* indeed special mineral manures may be said to be subservient to the increased growth of grain. And, the effect of alkalies upon leguminous plants, perhaps approaches more nearly to consistency with the theory of Baron Liebig than any other fact which has come under our observation, for the alkalies, which we have found to have a very marked effect upon their increased growth, predominate largely in their ashes.

A beautiful illustration of the dependence for luxuriant growth of one plant upon another of different habits, such as we have shown above, may be found in the case of the "fairy rings," where the fungus, by virtue of its extraordinary power of rapidly

accumulating nitrogen from the atmosphere during its growth, taking up the minerals which the grasses, from their more limited power in this respect, could not appropriate, an abundance ~~of provision~~ of the nitrogenous manure so effective in the growth of the grasses, which are observed to spring up with great luxuriance wherever the fungus has grown or fallen.

But again, judging from the composition of the ash of the turnip, which shows, both in the leaf and in the bulb, a proportion of alkalies to phosphoric acid of from four or five to one, we might be led to decide that the former, rather than the latter, were usually and specially the more appropriate manures for the turnip. Common practice has, however, definitely determined in favour of phosphoric acid rather than of the alkalies, as the special manure to be provided for the turnip, from sources external to the farm itself.

The striking effect of phosphoric acid upon the growth of the turnip, indeed, is a fact so well known to every intelligent agriculturist in Great Britain, that it would seem quite superfluous to attempt to illustrate it by any direct experiments of our own. However, as Professor Liebig has again, in the recent edition of his 'Letters,' expressed an opinion entirely inconsistent with such a result, we will refer to one or two of the results obtained in our experimental turnip-field, which bear upon the opinion he has reiterated as follows:—thus, speaking of the exhaustion of phosphate of lime and alkaline phosphates by the sale of flour, cattle, &c., he says:—"It is certain that this incessant removal of the phosphates must tend to exhaust the land and diminish its capability of producing grain. The fields of Great Britain are in a state of progressive exhaustion from this cause, as is proved by the rapid extension of the cultivation of turnips and mangold-wurzel, plants which contain the least amount of the phosphates, AND THEREFORE REQUIRE THE SMALLEST QUANTITY FOR THEIR DEVELOPMENT!"* Now we do not hesitate to say that, however small the quantity of phosphates contained in the turnip, the successful cultivation of it is more dependent upon a large supply of phosphoric acid in the manure than that of any other crop.

In the following table, then, is given the amounts of bulb† since 1843, of—

First, the continuously unmanured plot;
Secondly, that with a large amount of superphosphate of lime alone each year; and

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* See the third edition of the 'Letters on Chemistry,' page 522.
† Norfolk Whites in 1843-4-5-6-7-8, and Swedes in 1849 and 1850.

'hirdly, that with a very liberal supply of potash with some soda and magnesia also, in addition to superphosphate of lime.

Years.	Plot continuously Unmanured.				Plot with Superphosphate of Lime alone every Year.				Plot with Superphosphate of Lime and mixed Alkalies.			
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1843	4	3	3	2	12	3	2	8	11	17	2	0
1844	2	4	1	0	7	14	3	0	5	13	2	0
1845	..	13	2	24	12	13	3	12	12	12	2	8
1846	..	..	..	..	1	18	0	0	3	10	1	20
1847	..	..	..	..	5	11	0	1	5	16	0	0
1848	..	..	..	..	10	11	0	8	9	14	2	0
1849	..	..	..	..	3	15	0	0	3	13	2	8
1850	..	..	..	..	11	9	0	0	9	7	1	12
Totals.	..	..	..	..	65	16	1	1	62	5	1	20
Means.	..	..	..	..	8	4	2	4	7	15	2	20

It is seen then, that in the third season, viz. 1845, the produce of the unmanured plot is reduced to a few hundredweights, and since that period the size of the bulbs has been such that they have not been considered worth weighing. On the other hand, on the plot with *superphosphate of lime alone* for eight successive years, we have an average produce of about 8¼ tons of bulb! varying, however, exceedingly, year by year, according to the season. We see, too, that by the addition to superphosphate of lime of a large quantity of the alkalies, much greater than could be taken off in the crop, the average produce is not so great by nearly half a ton as by the superphosphate of lime alone. It must be admitted that this extraordinary effect of superphosphate of lime cannot be accounted for by the idea of merely supplying in it the actual constituents of the crop, but that it is due to some special agency in developing the assimilative processes of the plant. This opinion is favoured by the fact that in the case where the superphosphate of lime is at once neutralized by alkalies artificially supplied, the efficacy of the manure would seem to be thereby reduced. And from this again, we would gather that the effect of the phosphoric acid as such, cannot be due merely to the liberation within the soil of its alkalies, or we should suppose that the artificial supply of these would at least have been attended with some increase of produce. But this is not the case, notwithstanding that by means of superphosphate of lime alone there has been taken from the land more of the alkalies which the ash of the turnip so peculiarly abounds, than would have been lost from it in a century under the ordinary cou

of rotation and home manuring! Collateral experiments also clearly prove the importance of a liberal supply of organic substance rich in *carbon*—which always contains a considerable quantity of nitrogen also—if we would in practical agriculture increase the yield much beyond the amount which can be obtained by mineral manures alone; and these conditions being fulfilled, the direct supply of nitrogen, on the other hand, is by no means so generally essential. And it is where we have provided a liberal supply of constituents for organic formations, in addition to the mineral manures, that we have found the use of alkalies not to be without effect.

But it is at any rate certain that phosphoric acid, though it forms so small a proportion of the ash of the turnip, has a very striking effect on its growth when applied as manure; and it is equally certain that the extended cultivation of root crops in Great Britain cannot be due to the deficiency of this substance for the growth of corn, and to the less dependence upon it of the root crops, as supposed by Baron Liebig.

These curious and interesting facts in relation to the growth of turnips, as well as those which have been given in reference to wheat and to the leguminous crops, are sufficient to prove how impossible it is to form correct opinions on agricultural chemistry without the guidance of direct experiment in the field. And we are convinced that if Baron Liebig had watched the experiments which we have had in progress during the last eight years, he would long ago have arrived at conclusions in the main agreeing with those to which we have been irresistibly led: and we are disposed to believe that had he even seen the more detailed accounts of our results given in our own papers in this Journal, instead of the mere reference to them made by Mr. Pusey, he would rather have accepted them, as a step in an inquiry to which his own researches and writings had given such an impetus, than have designated them, as he has done, as entirely without value.

So much, then, for the results of experiments in the field, and for the considerations in relation to the functional actions of plants, as bearing upon the character of the manure required for their growth in a course of practical agriculture. Let us now consider for a few moments what really are the main and characteristic features of practical agriculture, as most generally followed in this country.

Let us suppose that the rotation adopted is that of Turnips, Barley, Clover, Wheat; that the turnips and clover are consumed upon the farm by stock, and that the meat thus produced, 40 bushels of barley and 30 bushels of wheat, are all the exports from the farm, the manure from the consumed turnips and clover,

and the straw, both of barley and of wheat, being retained upon the farm. We have in this case, by the sale of grain, a loss of minerals to each acre of the farm of only 20 to 24 pounds of potass and soda, and 26 to 30 pounds of phosphoric acid, in the course of the rotation, or an average of 5 to 6 lbs. of potass and soda, and 6½ to 7½ lbs. of phosphoric acid per acre per annum. In the sale of the animals there would of course be an additional loss of phosphoric acid, though, especially if no breeding-stock were kept, this would be even much less considerable than in that of the grain; and the amount of the alkalies thus sent off the farm would, according to direct experiments of our own upon Calves, Bullocks, Lambs, Sheep, and Pigs, probably be only about one-fourth that of the phosphoric acid. It has, however, long been decided in practical agriculture that phosphoric acid may be advantageously provided in the purchase of bones or other phosphatic manures, though in practice these are not found applicable as a direct manure for the wheat crop; and as we have already said, even when employed for the turnip, its efficacy is not to be accounted for merely as supplying a sufficiency of that substance to be stored up in the crop.

Of the minerals then, to be supplied by external sources yet to be discovered or developed, the question lies with the alkalies; and of these there will in the sales of corn supposed above, be, under any circumstances, only 5 to 6 lbs. per acre per annum required to be provided from the stores of the native soil by annual decomposition, in order that the immediately available supply of them, which has thereby been drawn upon, should be undiminished.

But we believe that few will maintain that the amounts of produce above supposed are, in practice, exported, unless under a system of purchased food for stock, or of such substances as rape-cake as manure for turnips; and by neither of these means could the produce thus be raised, without bringing upon the farm more of the alkalies than could possibly be exported, in the increased produce of corn and meat arising from their use. Under such a course, then, and this is what happens wherever land is well cultivated, the demand upon the native soil for alkalies, by the sale of corn, will probably be less than has been assumed; and it is even possible that in actual practice the available alkalies of the soil will, from the two causes of import and disintegration, accumulate rather than diminish.

In justification of the supposition that cattle-food must be imported, if the sales of corn and consequent export of alkalies are to be thus kept up, it must be remembered that the relative price of meat and corn, and that of manures to both, as fixed by the laws of supply and demand, would at present, at least, preclude

he idea of the produce of the latter, that is corn, being maintained respectively of that of the former—that is to say, by imported manures alone, and to the exclusion of the consumption of food upon the farm by stock. And here we might suggest as a consideration well worth the attention of practical men, as a test of the 'Mineral Theory," how it would be possible that the increased growth of wheat should be so limited and that its cost should be so great as in experience it is found to be, if the only manure required were the mineral constituents found in its ashes? And further, we would ask how, on the idea, on the other hand, that the nitrogen supplied in our manures determines the produce of wheat, they could account for the relative prices of wheat and ammonia, unless on the supposition that the expenditure and loss of the latter during the growth of the plant, is a fact which fundamentally affects the production and cost of grain in practical agriculture?*

But to return to our illustration. The animals kept upon the farm for *labour* too, must either consume part of the produce of the farm itself, in which case the sales of corn must be reduced, and consequently the exhaustion of the alkalies also, or they must be provided for by purchased food; in which case, while most or all of the minerals of such food will be retained upon the farm, much of its *Nitrogen*, and more still of its *Carbon*, will be lost by the vital processes.

It will be understood that the precise circumstances assumed in the illustration which we have given, will only be met with in certain cases, but whatever deviation from it may be found in ordinary practice in Great Britain, we believe that the line of argument here adopted is very generally applicable, and that it will also generally lead to a similar result.

It is true that owing to proximity to large towns, or other local circumstances, in many cases hay and straw, and even root-crops, may be sent off the farm; but in such cases local circumstances are generally found fully to compensate for this otherwise exhausting process, by the return of stable manure, night-soil, and other natural town manures. Indeed, that the alkalies are not relatively to nitrogen exhausted by the sale of straw in the neighbourhood of London, for example, is evident from the extensive use and marked effects even of soot and other non-mineral manures on the land from which this straw is taken. But if it were not so, such instances need not come into our calculations when speaking of agriculture generally.

But further, Baron Liebig has said that a knowledge of our

* One hundredweight of Peruvian guano will supply as much *phosphoric acid* as could be contained in about 18 bushels of wheat and its equivalent of straw—say 900 lbs.! And of *nitrogen* this quantity of guano will contain about as much as 1 bushels of wheat and 1100 lbs. of straw!

experience of fallow is sufficient to show the fallacy of our opinions; but in this very process, and that even of liming also, when rightly considered, we believe we see that which should give confidence in the views we have maintained. It cannot be doubted that by the processes of fallowing and liming the disintegration of the minerals of the soil, and the increase of the available supply therefore of their several constituents, must thereby be enhanced. But notwithstanding we have in the direct experiments of Wiegmann and Polstorff, of Rogers, and others, sufficient evidence of such disintegration under the action of air and water; yet there is, in our opinion, equal reason for believing that the processes of fallowing and liming owe their efficacy, as much or more to the changes which take place within the soil in regard to the available supply of the nitrogen which plants require, as of their purely mineral constituents. Thus Professor Mulder has concluded that the organic acids of the soil which he has investigated, have the power of accumulating ammonia from the atmosphere. Now these compounds will only be *retained* within the soil where organic matter is subject to a very slow process of decomposition, and it is precisely in the *heavier soils*, where the processes of fallowing and liming are found to be most beneficial, that organic matter will be shut up and subject to a very slow decomposing action, which these processes will materially assist. But more important still;—the experiments of Mr. Way on the absorptive properties of soils have directly proved, what was before indeed supposed, that it is the heavier soils, those again therefore that are most influenced by fallowing and liming, that possess in the highest degree the power of absorption and retention of ammonia and other substances, to the action of which they may be exposed. We do not, indeed, mean to say that the processes in question owe their value entirely to the influence of the actions to which we have alluded; but we think it may reasonably be suggested that there is, at least, as much evidence in favour of this view of the efficacy of fallowing more especially, as in the mineral theory of it; and the more so when we remember that it is the wheat crop, for which nitrogen *in the soil* is found to be so important, that almost invariably succeeds the fallow. And the fact that mineral substances do at the same time accumulate, should itself give confidence in views which, on independent grounds, suppose that they are not so easily liable to be found in defect in relation to other necessary supplies.

Reviewing, then, the actual facts of practical agriculture, as generally followed in Great Britian, we have seen how small is the utmost annual loss of alkalies under the export of corn and meat alone, and that the demand thus made upon the stores of the native soil will generally be truly insignificant. Phosphoric

acid, on the other hand, is sent off the farm in much larger quantities than the alkalies; but under good cultivation it is already in actual practice frequently more than restored by the import of cattle food, or direct manures, such as bones, guano, &c. Baron Liebig, indeed, himself asserts that farm-yard manure is the universal food of plants; and we should never lose sight of the fact, that the very practice of agriculture in this country necessitates the production of this manure, by means of which it is that so large a proportion of the mineral elements of the crops raised upon the land are in due time restored to it: all our calculations, therefore, should be made on a full consideration of what is involved in its use. This is, however, not generally sufficiently borne in mind by chemists unconnected with practical agriculture; and to this cause may, in great part, be attributed the reiterated recommendations to imitate in artificial manures the composition of the ashes of the plants to be grown.

But further than this, taking into careful consideration the tendency of all experience in practical agriculture, as well as the collective results of a most laborious experimental investigation of the subject, both in the field and in the laboratory, it is our deliberate opinion that the analysis of that portion of a crop which is sent off the farm, whether of its organic substance or of its ashes, is no DIRECT guide whatever as to the nature of the manure required to be provided for its increased growth in the ordinary course of agriculture, from sources *extraneous to the home manures of the farm;* that is to say, by artificial means.

In conclusion, then: if the theory of Baron Liebig simply implies that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up, we fully and entirely assent to so evident a truism; but if, on the other hand, he would have it understood that it is of the mineral constituents, as would be *collectively* found in the ashes of the exported produce, that our soils are deficient relatively to other constituents, and that, in the present condition of agriculture in Great Britain, "we cannot increase the fertility of our fields by a supply of nitrogenized products, or by salts of ammonia alone, but rather that their produce increases or diminishes, in a direct ratio, with the supply of mineral elements capable of assimilation," we do not hesitate to say that every fact with which we are acquainted, in relation to this point, is unfavourable to such a view. We have before stated, however, that if a *cheap* source of ammonia were at command, the available mineral constituents might in their turn become exhausted by its excessive use.

Baron Liebig states indeed (see *Letters on Chemistry*, p. 519), that his views are "in no respect inconsistent with the good effects of an artificial supply of ammonia;"—that "a supply of it is always

beneficial, and for certain objects indispensable;"—and that it "accelerates* the development of cultivated plants;"—ideas which, we would submit, are not consistent with the supposition of a relative deficiency of minerals in our soils, and which, if he carried out to their consequences, would materially lessen the difference between his opinions and our own. But as he says in the same page, that "if the mineral elements, phosphates, &c., be duly supplied, the plant will obtain a sufficient supply of ammonia from the atmosphere," the practical utility of its application by artificial means would seem at the same time to be put out of the question.

He further states (p. 519) that "the supply of ammonia is for many of our cultivated plants unnecessary and superfluous." This seems fully to imply a distinction among the plants grown in our rotations, as regards their demand for nitrogen accumulated in the soil in the course of cultivation, and, in fact, that for some plants such a supply *is* necessary. Here is a point which we have claimed to be intimately connected with the utility of a rotation of crops. But when he says in the same chapter (p. 514), "Surely the cerealia and leguminous plants which we cultivate must derive their carbon and nitrogen from the same source whence the gramineous and leguminous plants of the meadows obtain them," he would seem to bring all again within one category.

In another chapter (p. 524) he says that if "a rich and cheap source of phosphate of lime and the alkaline phosphates were open to England, there can be no question that the importation of foreign corn might be altogether dispensed with after a short time." But it is at any rate certain that for *wheat*, of all our crops, no supply of minerals, phosphates, &c., to the fields of Great Britain generally, will enable it to "obtain a sufficient supply of ammonia from the atmosphere;" and, indeed, that any increased produce of it, such as British agriculture (itself so artificial) demands, cannot be obtained independently of an artificial accumulation of nitrogen *within the soil.*

Of those crops of rotation, on the other hand, where the effect of mineral manures is characteristically to increase the assimilation of nitrogen from atmospheric sources, and by virtue of which property they indeed become subservient to the increased growth of grain, the apparent demand for these substances is not only generally not such *in kind* as would be indicated by an analysis of their

* At the recent meeting of the British Association at Ipswich, where the substance of this paper was given, Dr. Daubeny brought forward Baron Liebig's admission of the "acceleration" of the growth of plants by ammonia, as showing his recognition of the importance of its artificial supply; and hence, to avoid misconception, it seemed desirable, by means of further quotations, to show what really are the views of Professor Liebig on this point.

ɔut is frequently much greater *as to quantity* than can be ed for by any idea of merely supplying what is to become al constituent of the crop. If, then, we would attain by the cience a rational system of agriculture, the actual facts of itself, as well as the indications of direct experiments in d, and a study of the functional actions of plants and , must receive a due share of our attention. In fact, ry *alone* will do nothing for practical agriculture.

E.—This important paper so completely establishes what in our last Number on the entire failure of the Mineral as a guide to the use of manures in practical farming, that only express my regret for the annoyance which its author blicly expressed, as I am told, at those remarks. In ing the English farmer against what seemed to me a dan- error, I certainly endeavoured to do justice to the real ries of Baron Liebig. Since the experiments, however, of awes and Dr. Gilbert have, as I hear, been disputed, ɔund to say that my confidence in the scrupulous accuracy gentlemen has been only strengthened by a subsequent Rothamsted, in company with that eminent philosopher Dumas. The extent of the experimental ground—the ture at which it has been kept up—the perseverance with ear after year, it has been maintained, are such as might e expected from a public institution than a private land- nd render Rothamsted, at present, the principal source orthy scientific information on Agricultural Chemistry.

PH. PUSEY.

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ON THE

AMOUNTS OF, AND METHODS OF ESTIMATING,

MONIA AND NITRIC ACID

IN

RAIN-WATER.

BY

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ON THE

AMOUNTS OF, AND METHODS OF ESTIMATING,

AMMONIA AND NITRIC ACID IN RAIN-WATER.

The character and amount of the extraneous matters in rain-water are questions of interest in so many points of view, that little apology need be made for recording, under the auspices of the British Association, any additional information on that subject. Of all such extraneous matters, the ammonia and nitric acid are of importance in the most numerous aspects. Thus, their existence in the atmosphere, from which they are washed by the rain, is primarily dependent, largely at least, on the emanations from the surface of the earth, resulting more or less directly from the decomposition or combustion of animal and vegetable substances, and the transformation of the animal substance by the vital process. Their amounts therefore must be greater or less in the lower strata of the atmosphere, according to the local prevalence of animal life and other causes, whilst the relative amounts of the two, especially in the higher strata of the atmosphere, will be dependent on its meteoric or electrical condition. Again, whatever may be their source or amount, or their proportion to each other in the atmosphere itself, the amounts of them which are carried down in rain and the minor aqueous depositions from the atmosphere in any given locality, over any fixed period of time, or according to other circumstances, must be of interest at once in a sanitary, in a meteorological, and in an agricultural point of view.

It is to Cavendish that we are indebted for the observation, that ammonia and nitric acid are formed when humid air is submitted to voltaic action. About the commencement of the present century, De Saussure detected ammonia in the atmosphere. A few years later, Chevreul observed its presence in the Seine; and in 1825, Brandes detected it in rain-water. Since that time much more minute attention has been paid to this subject, and also to the presence of *nitric acid* in rain and other waters. Liebig, and Boussingault, have particularly called attention to the influence which the ammonia carried down from the atmosphere must have upon the growth of plants; and the former of these philosophers pointed out the occurrence of nitric acid also, in a considerable number of rain-waters which he examined, especially in those of thunder-storms; though to the *amount* of nitrogen so brought down he attached little importance. Dr. H. Bence Jones has also found nitric acid in the rain which fell in various parts of England and in the south of Ireland.

But it is to the more recent labours of Boussingault that we are indebted for our most elaborate *quantitative* estimations of the *ammonia* in rain and other waters; and M. Barral has made a series of quantitative determinations of the *nitric acid* as well as the ammonia, contained in the rain which fell at Paris during several consecutive months in 1851. Our own object in entering upon the same field of *inquiry*, was chiefly with a view to the

agricultural bearings of the subject. But the conduct of an investigation involving at once the treatment of large bulks of material, and the determinations in them of infinitesimally small amounts of the substances sought for, is attended with many practical difficulties: and the scope and object of the present paper is rather to discuss the methods of analysis, than to rely with confidence on the conclusions to which we might be led by the direct application of the numerical results yet obtained, to the solution of the several important scientific and practical questions upon which they bear.

In the Tables which follow are given the results obtained in the estimation of *ammonia* in rain-water by several different methods. In the first instance, very large amounts (from 100 to 200 lbs. or more) of rain-water, to which a little caustic potash was previously added, were distilled, and the distillation of the product repeated, collecting in each case about one-half the amount put into the retort, until the whole was reduced to a convenient bulk for further treatment. This was then evaporated in an open vessel, with a known amount of sulphuric acid *to a given volume*. Measured portions of this acid product were then neutralized by a standard alkaline solution, in the usual manner of liquid analysis. This process we designate as "Method 1."

The system of graduation adopted throughout the experiments was that of septems, this being generally employed in water analyses in Great Britain. As cubic centimetres and litres are generally adopted abroad, it may facilitate the conception of those accustomed to the latter measures, to state, that the septem is equal to 7 grains of water at 60°; that 1000 septems are equal to a decigallon, or 1 lb.: and 10,000 septems consequently are equal to 1 imperial gallon. A cubic centimetre, on the other hand, is equal to 1 gramme, or rather less than 15½ grains: and 1000 cubic centimetres, or grammes, are equal to 1 litre. Consequently, for the purposes of a general conception merely, a cubic centimetre may be considered as equal to 2½th septems, and a litre to 2½th decigallons, or lbs. avoirdupois. We shall, however, always give the amount of ammonia found in *one million* parts of rain-water, which is precisely equivalent to the scale of milligrammes of ammonia per litre (1,000,000 milligrammes) of water, as adopted by MM. Barral, Boussingault, and others. The sulphuric acid used in the determinations made by *Method* 1, was at "10°" strength, 1000 septems of which contain 50·1 grains (one tenth the combining number) of the dry acid; 1 septem, therefore, of this liquid acid contains 0·0501 grain of the dry acid, and is equivalent to the neutralization of 0·02145 grain of ammonia, which is $=\frac{1}{10.000}$th of Berzelius's number for ammonia. The acid was prepared by dissolving 66·73 grains (one tenth the combining number) of pure carbonate of soda in 1000 septems, or a decigallon, of distilled water at 60°, and then making a previously dilute acid to exactly the same strength, volume for volume, by the usual alkalimetrical method; and, from this acid at 10°, the standard caustic alkali solutions were made of a like strength, in a similar manner. The above acid is exactly one-seventh the strength of Peligot's acid.

In Table I. which follows, are given the results of the determinations of the ammonia by this "*Method* 1," in the mixed sample for each month, of the rain which fell in March, April, May, June, July, and August, of 1853. The quantities operated upon were one-half or one-fourth of the total amounts collected in each month, in a rain-gauge of exactly $\frac{1}{100}$th of an acre area (43·56 square feet).

TABLE I.

1.—The Rain twice distilled to $\frac{2}{3}$ths with a little caustic alkali, and second distillate evaporated with sulphuric acid to the measure of septems. (Year 1853.)

aths.	lbs. of rain distilled.	Septems of sulphuric acid at 10° added to second distillate.	Septems of alkali at 10° to neutralize 100 septems of concentrated acid product.	Difference — septems ammonia at 10° in 100 septems acid product.	Grains of ammonia in rain-water taken.	Ammonia per million of rain-water.
ch ...	267·2	300	17·5 17·5	12·5 12·5	2·681	1·433
il.....	169·6	400	35·5 35·5	4·5 4·5	0·965	0·812
'	95·2	300	25·5 25·5	4·5 4·5	0·965	1·448
e.....	175·2	700	62·0 62·0	8·0 8 0	1·716	1·399
'	213·0	500	43·5 43·5	6·5 6·5	1·394	0·935
ust...	167·9	400	35·5	4·5	0·965	0·821

seen that the smallest quantity of water submitted to distillation in ies of experiments was about 95 lbs., and that the largest was about . To the second distillate of $\frac{2}{3}$ths of the amount put into a retort of ith a little caustic alkali, the quantities of sulphuric acid at 10° given mn 3 were added, and the whole was then evaporated to the measure 0 septems at 60°. One-tenth of this, or 100 septems, after being d by a given measure of infusion of litmus carefully freed from excess li, was then tested with a caustic alkali solution, also at 10°. It was bly found, that, with liquids of this degree of concentration, the deter- n could be made to a single drop of the test alkali. This would give num range of error of about $\frac{1}{50}$th, or 2 per cent. of the whole am- contained in the water, dependent on the manipulation of the test

It was still a question whether there might not be some source of ther in assuming with M. Boussingault that the whole of the ammonia e obtained in a $\frac{2}{3}$ths distillate, or in supposing that there would be no ber of ammonia or of acid, in the evaporation of the acidulated di- in open vessels. By the comparison which will presently be made, r, between the above determinations by Method 1, and others in ns of the same waters by Method 2, which in fact is that adopted by ssingault, it will be seen that there was probably no error due to f the causes just suggested. In fact we conceive that the method of stillation, with subsequent acidulation and concentration of the di- to a given measure of fluid, and the use of comparatively strong test is capable of giving very good results ; but it was necessarily aban- from the great practical inconvenience, and frequent breakage, in ting distillations in glass on so large a scale.

ne next Table (II.) are given the actual results obtained by Method 2 ; is substantially *that of M. Boussingault.* M. Boussingault's process *in submitting to a single distillation*, generally not more than 1 litre

(about 35¼ ounces) of water, and collecting and testing by the alkalimetrical method, two or more successive fifths or tenths of the product. For this purpose M. Boussingault uses a test acid little more than ¼th the strength of our acid at 10°, and only $\frac{1}{40}$th the strength of the test acid of M. Peligot. His test alkaline solution, again, is not quite ⅓rd the strength, volume for volume, of his test acid. In practice he finds that the limit of error in the use of this dilute alkaline solution is about 0·2 cub. cent. measures of it, equal to about 0·033 milligramme, equal to 0·0005 grain of ammonia. This, equal to about $\frac{1}{3000}$th of a grain only, is certainly a suprisingly small *actual* amount of ammonia to determine by analysis; but when it is considered, that in the quantity of water operated upon by M. Boussingault, there is seldom 1 milligramme=0·0154 grain of ammonia, it is obvious that an error of only 0·033 milligramme or 0·005 grain, however small in *actual* amount, is still considerable in the relation to the whole to be estimated, amounting in the case supposed to about $\frac{1}{30}$th or 3⅓rd per cent. But when we further consider, that the total amount of ammonia in a litre of water is frequently considerably less than a milligramme, and also that this total amount, whatever it may be, is divided for testing into two or more seperate portions of the distillate, it is obvious that the minimum range of error, especially in the testing of the weaker portions, must be very considerable indeed in proportion to its whole amount. We have, however, had the privilege of witnessing the conduct of the process in the hands both of M. Boussingault and of his able assistant M. Houzeau, and certainly with suprising uniformity of result.

In Table II. are given the actual results of experiments in the Rothamsted Laboratory, in which 60 ounces, instead of only 1 litre, were generally submitted to distillation; and although the greatest care was taken, it must be admitted that in these first results of unpractised hands, neither was the relation of the ammonia in the successive portions of the distillate so uniform as in the experiments of M. Boussingault, nor were the total amounts of ammonia found in duplicate specimens of water so coincident as could be wished. But it must be clearly understood, that attention is called to this point not in the least with the view of depreciating the admirable labours of M. Boussingault, which we are satisfied have been conducted with the utmost accuracy of which the process is capable, but it seems desirable to point out how serious may be the proportional error in less constantly practised or less careful hands.

It should be mentioned, that in our conduct of this Method 2, in all cases excepting for the month of April, a test acid of 1° strength only was employed; that is to say $\frac{1}{10}$th the strength of that used previously, and it was moreover only about ⅔ths the strength of Boussingault's acid. The test alkali, on the other hand, was, for the rain of the first four months, at 1°, and afterwards at only ½° strength, which latter is very nearly identically the same as that used by Boussingault. We sought to measure too, to a ¼th of a septem of the stronger, and ½ a septem of the weaker alkaline test-liquor, which respectively represented 0·034 milligramme, or 0·00054 grain of ammonia, almost identically the same degree of accuracy as that attained by M. Boussingault in measuring to 0·2 cub. cent. of his alkali=0·033 milligramme of ammonia. The fractional distillates were collected in small flasks marked according to the quantity to be collected, each of which, when filled, was corked up until the series was ready for testing. An equal measure of pure distilled water was then put into a test-glass side by side with the distillates, and to it was added the same measure of litmus *and acid as to the* rain producta. This being neutralised with its exact *equivalent of the* test-alkali, furnished a guide as to the tint to be aimed

he other testings, which were then performed as rapidly as possible, ent the absorption of carbonic acid from the atmosphere. It was by numerous trials, that this adoption of a standard—and com- rith the method of M. Boussingault somewhat more permanent point ration—gave us greater uniformity of result in duplicate experiments uids of known strength, than that of taking the point of first perfect n of blue colour throughout the liquid, as adopted by Boussingault; e test-liquors were therefore arranged accordingly. It should be hat the rapid diffusion of the alkali through the liquid was favoured easing its specific gravity by the addition of neutral sulphate of as employed by M. Boussingault for that purpose.

Table II.

2.—By the single distillation of small quantities of water (with i), and testing successive portions of the distillate according to singault.

ss. / a.	Experiments.	Ounces of rain-water.	Septems of Ammonia at 1° in portions of distillate.							Ammonia per million rain-water.
			1st tenth.	2nd tenth, or 1st fifth.	3rd tenth.	4th tenth, or 2nd fifth.	5th tenth.	6th tenth, or 3rd fifth	Total.	
...	1	30	...	4·0	...	1·0	...	...	5·0	0·817
	2	30	...	4·0	...	1·0	...	...	5·0	
....	1	30	...	4·5	...	2·0	...	1·0	7·5	1·225
	2	60	7·0	3·0	2·0	2·0	...	...	14·0	
	3	60	8·0	4·0	2·0	2·0	...	...	16·0	
.....	1	60	7·5	2·5	1·5	1·5	1·0	...	14·0	1·144
.....	1	60	5·0	2·5	2·0	1·0	1·0	...	11·5	0·939
	1	60	4·5	1·5	1·5	1·0	1·0	0·5	10·0	
...	2	60	5·0	1·75	1·5	1·5	1·0	...	10·75	0·851
	3	60	4·75	2·0	1·5	1·25	1·0	...	10·5	
	1	60	4·5	2·0	1·0	0·5	0·0	...	8·0	
	2	60	4·5	1·5	1·0	1·5	1·5	...	10·0	
ber	3	60	4·75	2·0	1·5	1·0	0·5	...	9·75	0·735
	4	60	5·0	1·75	1·0	0·5	0·5	...	8·75	
	5	60	4·75	1·5	1·0	0·75	0·5	...	8·5	
	1	60	4·75	1·5	0·75	0·5	0·5	...	8·0	
r	2	60	4·5	2·25	1·5	0·75	0·75	...	9·75	0·688
	3	60	4·0	1·25	1·0	0·75	0·5	...	7·5	
	1	60	5·0	1·5	1·25	0·75	0·5	...	9·0	
ber	2	60	6·0	2·0	1·25	0·75	0·5	...	10·5	0·803
	3	60	6·0	1·25	1·5	0·5	0·75	...	10·0	
ber	1	60	12·75	3·25	2·0	1·0	1·0	...	20·0	1·614
	2	60	12·5	3·5	1·5	1·0	1·0	...	19·5	

eference to the figures in the Table it may be mentioned, that M. ngault found that each successive tenth of the distillate contained e ammonia only of its predecessor, and that the whole appreciable nia was generally contained in the first four or five tenths. It is seen nis rule as to the proportional diminution of the ammonia in the nal distillates is not well borne out in the figures of our Table; and gh we do not call in question the fact of this actual relationship in an ely uniformly conducted series, yet it would seem that in practice it easy to attain it. Nor can we be much surprised at the difference in ount of ammonia indicated in the "total" column in cases of dupli- alyses, *when we remember that* each *total* is the sum of the amounts

obtained in four or five separate testings, in each of which the minimum error of observation is 0·25 of a septem of ammonia at 1°, and that it requires considerable practice, and some dexterity and accuracy of observation, to avoid a greater range of error. Upon the whole, then, considering that in operating upon only a single litre of rain-water, the minimum error of observation, if any, will even with the most perfect manipulation generally amount to 3 or 4 per cent. of the total ammonia contained in the water, and further, that in any but the most practised and skilful hands the error may be much more than that supposed—indeed more than multiplied by the number of testings—we were led to abandon this second method also, notwithstanding its very obvious advantages so far as convenience and rapidity are concerned. These objections will of course apply with still greater force when rains containing less than the average amount of ammonia are operated upon, and especially in the case of the waters of springs and rivers, the average amount of ammonia in which would seem, according to M. Boussingault, to be very considerably less than in any rain-waters.

In subsequent experiments, therefore, we adopted the plan of operating upon several litres of water in the first instance, reducing the bulk by successive distillations to one-half, until thus brought to a convenient amount for final distillation, and subsequent testing of measured proportional amounts of the distillate in the manner described in reference to Method 2. This modification, we have since observed, was suggested by M. Boussingault himself, but it would seem he did not generally adopt it. In the next Table (III.) are given the results obtained by this *Method* 3, in which 3, 6, or 12 lbs. of the rain-water were first operated upon, these quantities, as the case might be, being reduced to 24 ounces by successive distillations as stated above. This product was then finally distilled, and the distillate fractioned into quarters, the first three of which were separately supersaturated with the test-acid at 1°, and subsequently neutralized by the test-alkali at ½°.

Table III.

Method 3.—Distillations to one-half, until reduced to 24 ounces, redistilled, and successive quarters tested.

Year 1854. Months.	Experiments.	lbs. of rain-water taken.	Septems of ammonia at 1° in 1st quarter.	2nd quarter.	3rd quarter.	Total.	Ammonia per million rain-water.
January	1	6	12·5	1·25	1·5	15·25	0·779
	2	6	13·5	0·75	1·0	15·25	
February	1	3	6·5	1·5	1·25	9·25	0·945
	2	3	6·75	1·5	1·00	9·25	
March...	1	3	8·25	0·75	0·25	9·25	0·945
April*...	1	12	34·50	1·75	1·0	37·25	0·967
	2	12	35·25	2·25	1·0	38·50	
May.....	1	12	16·5	1·25	1·0	18·75	0·469
	2	12	16·25	1·00	0·75	18·00	

* April checked by Method 2.

Water.	Tenths. 1st.	2nd.	3rd.	4th.	5th.	Total.	per million.
60 ozs.	9·0	1·5	0·5	0·5	0·5	12·0	0·960

A glance at the columns of detail of this Table clearly illustrates the fact pointed out by M. Boussingault, upon which this method of determining the ammonia in rain and other waters is based, namely, that in the case of very dilute solutions of the volatile alkali, nearly the whole of it passes over in the first portions of the distillate. We observe, however, that even where the "total" amount of ammonia obtained from duplicate specimens of water is the same, or very nearly so, still the quantities determined in the corresponding fractional parts do not always agree so well. This would seem to indicate that the discrepancy is due to irregularity in the distillation, rather than to error of observation in the testing. It is true, that this method of successive distillations is much more tedious and troublesome than the method of small single distillations preferred by M. Boussingault; and even with it, it would appear, as in one or two cases in Table III., that the difference between the amounts of ammonia determined in duplicate specimens of rain-water, may in practice be nearly as great in proportion to the whole, as that which is assumed to be a not necessarily exceeded range of error in the method of small single distillations. Upon the whole, however, we consider the modification involved in this Method 3, to be practically very important, and that this form of the process of estimation by distillation is much more applicable to this delicate subject of inquiry than either of those which we have previously adopted.

Before leaving the question of *method*, it may be well to enumerate the calculated minimum proportions of error by the different methods, supposing that in Methods 2 and 3 equally with Method 1, this error would necessarily only occur once in a total estimation. This however is not the case; for it is obvious, that in practice it might tend in the same direction in the estimation in each fraction of the distillate. It is on the other hand of course possible, that the error, if it existed, might be counterbalanced among the several fractions.

Taking first Method 1, and supposing one-tenth of the concentrated acid product of 100 litres of water to be finally tested, this would, on the average of the amounts found in the rain at Rothamsted, contain 10 milligr.= 0·1543 grain of actual ammonia. Assuming also, as was found in the practice of the method, that the degree of accuracy easily attainable in the use of the acid and alkaline test liquors at 10°, indicated 0·2 milligr.=0·0031 grain of ammonia, this range of error would obviously amount to $\frac{1}{50}$th, or 2 per cent. of the whole ammonia contained in the product tested: and it should be borne in mind, that so far as the *testing* was concerned, there was no difficulty whatever in obtaining duplicate estimations which agreed absolutely together; so that the amount of error in a series was certainly not more in practice than that supposed. The difficulty with this method however was, as before stated, in the management of such large distillations in glass vessels.

In Method 2, that of M. Boussingault, 0·033 milligr. of ammonia are supposed to be determined, and the amount of water operated upon to be 1 litre. The average amount of ammonia in 1 litre of the rains collected at Rothamsted is about 1 milligr., or 0·0154 grain; so that the minimum limit of error would obviously be 3·3 per cent. of the whole amount in such a case. The average quantity of ammonia per litre found by M. Boussingault in the rain of the open country does not exceed 0·8 milligr.; in which case the minimum error in estimating to 0·033 milligr. would amount to $\frac{1}{24}$th, or rather more than 4 per cent. of the whole. In the water of *rivers*, the average amount of ammonia, *according to M.* Boussingault, was not quite 0·2 milligr. per litre; *upon which, determining* only to the same amount as before, the

error might be between $\frac{1}{5}$th and $\frac{1}{6}$th, or about 16·5 per cent. of the whole. In *spring-water*, again, M. Boussingault found generally only about half as much ammonia as in rivers; in which therefore the smallest error in the determination in 1 litre only, would amount to about $\frac{1}{3}$rd of the whole.

According to Method 3 again, assuming that 12 lbs. of water (=about 5½ litres) were used, this, taking the average composition of the Rothamsted rains, would contain about 5½ milligr. of ammonia; and determining as we calculated to do, to 0·034 milligr., the minimum error would thus be about $\frac{1}{160}$th, or about 0·6 per cent. of the whole. The probability of accuracy, therefore, so far as the process of liquid testing is concerned, would be greatly in favour of the third method, that of successive distillations.

At the foot of Table III., however, is given the determination of ammonia in the rain of April 1854, according to Method 2, which indicates by the method of small single distillation 0·98 ammonia per million of water, by the side of 0·967, as obtained by the method of successive distillations; figures which coincide sufficiently to give confidence at least in the approximative truth of the results obtained by the two methods. This brings us to a further consideration of the proportions of ammonia found in the rains collected at Rothamsted by the different methods, and of the actual amounts contained in the water which fell over a given area in different seasons; and also to a comparison of our own results with those obtained by other experimenters in other localities.

TABLE IV.—Showing the proportion of ammonia per million rain-water, and the lbs. of ammonia in the monthly rain per acre, in different localities and seasons, determined by different experimenters, and by different methods.

Months.	Ammonia per million rain-water.					lbs. of ammonia per acre.			
	Paris.	Liebfrauenberg.	Rothamsted.			Paris.	Rothamsted.		
	1851.	1852.	1853.		1854.	1851.	1853.		1854.
	Barral.	Boussingault.	Meth. 1.	Meth. 2.	Meth. 3.	Barral.	Meth. 1.	Meth. 2.	Meth. 3.
January ...				.....	0·779	.....	.....	.....	0·32
February ...				.....	0·945	.....	.....	.....	0·20
March			1·440	.....	0·945	.....	0·77	.....	0·11
April			0·812	0·817	0·967*	.....	0·55	0·55	0·11
May		0·624	1·448	1·225	0·469	.....	0·55	0·47	0·46
June		0·415	1·399	1·144	.....	.....	1·07	0·88	
July		0·435	0·935	0·939	.....	.....	0·95	0·96	
August ...	2·98	1·494	0·821	0·851	.....	0·75	0·55	0·57	
September	3·81	0·745		0·735	.....	1·00	.....	0·33	
October ...	1·08	0·721		0·688	.....	0·51	.....	0·57	
November.	1·17			0·803	.....	0·45	.....	0·37	
December .	8·38			1·614	.....	1·34	.....	0·15	
Means...	3·49	0·744	1·142	0·979	0·821	0·81	0·74	0·54	0·24

* By Method 2, 0·980.

In Table IV. are given,—

The amounts of ammonia *per million*, in the rain which fell at Paris during several consecutive months of 1851, as determined by M. Barral;

The proportions determined by M. Boussingault in the open country in Alsace, during several months of 1852;

The proportions in the rain which fell at Rothamsted during several months of 1853, in several cases determined both by Methods 1 and 2; also in that of several months of 1854 determined by Method 3.

And in the second division of the Table,—

The actual amounts of ammonia *in lbs.*, contained in the rain which fell over the area of an imperial acre, in the case of each of the months experimented upon by M. Barral at Paris, and by ourselves at Rothamsted.

Comparing together the determinations of the ammonia per million of the rains collected at Rothamsted in April, May, June, July, and August 1853, made by both the Methods 1 and 2—in the one case dealing with hundreds of lbs. of rain-water, and in the other with only 30 or 60 ounces of it—the coincidences are such as to lead to the conclusion, that such discrepancies as there are, are due to manipulative difficulties and irregularities, rather than to erroneous principles inherent in the methods themselves. In the determinations for May and June, those made by method 2 are indeed notably below those made by Method 1. But the obvious deviation from the regularity in the proportion of the ammonia found in the different fractional portions of the distillate, as seen in the detail of the determinations given in Table II., compared with that supposed by M. Boussingault to be so uniform, would lead to greater confidence in the estimations made by Method 1. Confidence in the general principles of the various methods is, however, again afforded by a comparison of the determination made in the rain of April by Method 3, with that made in the same water by Method 2 as given at the foot of the Table; the former giving 0·967, and the latter 0·980 parts of ammonia per million of the water.

Trusting, then, as we may do, in the general approximative truth of the results obtained, we find, that taking all the determinations in the monthly rain collected at Rothamsted given in this Table, and which apply to that of fourteen separate but consecutive months, the average amount of ammonia is almost exactly *one part in a million of the rain*. The average of Boussingault's determinations in the open country of Alsace, and extending over six months of the year 1852, from May to October inclusive, is seen to be as nearly as possible $\frac{3}{4}$ths of the amount found at Rothamsted. The estimations of M. Barral, on the other hand, in the rain collected at Paris during five consecutive months of 1851, from August to December inclusive, give an average of nearly $3\frac{1}{2}$ parts of ammonia in a million of rain-water; and, in subsequent experiments, M. Boussingault has found the ammonia in the rain at Paris to be as great as that observed by M. Barral. There can be no doubt, therefore, of the influence of a large city teeming with animal life, and in which combustion of various kinds is so enormous, upon the proportion of ammonia in the ambient atmosphere, and consequently on the amount of it which will be washed down in the rain.

In what manner, however, locality, strictly so speaking, influences the actual amount of ammonia from surface emanations or otherwise, in otherwise equally open country, is still a question. But in reference to the *proportion* of it in a given amount of rain, it is at any rate interesting to observe, that the variations which we found in the amount of the ammonia in rain of different but entire months, *when considered* in connexion with the registered

amounts of the fall, the direction of the wind, and the general character of the weather, are perfectly consistent in kind with the results obtained by M. Boussingault in his special examinations of rain falling under different circumstances, of the water of dews, of fogs, &c. Thus, M. Boussingault always found a very obvious connexion between the amount of rain which fell in individual showers, and the *proportion* of ammonia in the water collected; there being more ammonia per million of the water the less the amount of the fall. There was also much more ammonia at the commencement of a shower than at the end of it, and after a drought than in continuously rainy weather; though a comparatively short cessation of the rain was sufficient again notably to increase the proportion in the water collected. In the water of dews and fogs, again, he found the proportion of ammonia very high.

From the above facts it would seem, that the proportion of ammonia found in the aqueous deposits from the atmosphere was greatly dependent on the amount of those deposits; or, in other words, on the degree in which they diluted the soluble matters brought down by them from the atmosphere. Turning now more directly to the evidence of our own figures in reference to these points, it is at once obvious, that the period of the year has of itself no direct influence on the proportion of ammonia in the rain; for we find that this is three times as great in the water of May 1853 as in that of May 1854; the proportion found in the latter being the lowest, and that in the former nearly the highest, in our entire series of experiments. And that this was directly due in great part merely to dilution, is obvious from the fact, that whilst there was comparatively little difference in the *actual amount* of ammonia brought down over a given area in the two cases, yet with the small *proportion* of ammonia in the rain of May 1854, the fall was nearly three times as great as in May 1853. The largest *proportion* of ammonia throughout the entire series was, however, in December 1853; and here it was that we had also the smallest fall of rain among the whole fourteen months submitted to experiment. But again, with this very large proportion of ammonia *per million of the rain*, there was during this month of December 1853, as is seen in the second division of the Table, very nearly the smallest *actual amount* of ammonia washed from the atmosphere of any case in our series. Bearing in mind these facts, it will be only what would be expected, that we find the highest proportion of ammonia with prevailing northerly and easterly winds, and the lowest with prevailing southerly and westerly ones; but since the former are generally coincident with a low, and the latter with a high amount of rain, any supposed material influence of the direction of the wind might probably much more properly be referred to the amount of the fall, or in other words, to the degree of dilution.

In the same manner, since with storms we have frequently a considerable total fall, whilst with dews, mists, and fogs, the aqueous deposition is comparatively small, any direct influence which the conditions of atmosphere involved in these states of the weather might have (apart from those inherent in the more general character of the season, or of local circumstances), either upon the formation, or emanation, or the slow or rapid condensation of ammonia, or upon the lessening of its amount by its conversion into nitric acid, is not at once obvious on the face of the figures of the Table. Still, on careful consideration of our notes as to the general character of the weather of the different months, taken in connexion both with the proportion of ammonia in the water collected, and with the total amount of it brought *down at different seasons* over a given area of land, seems to indicate that

the prevalence of thunder-storms has not of itself the tendency to increase the amount of nitrogen brought down in the form of ammonia. And, even supposing that the frequent occurrence of storms during the warmer months were found to be coincident with a large actual deposition of ammonia, it might still be a question whether such a result were not dependent on other characters of the season, or the conditions of the lower strata of the atmosphere, and their connexion with the surface, rather than upon those of the higher strata, or the circumstances more directly leading to the development of the storms. At any rate it is worthy of remark, that in the month of May 1854, which was characterized by the occurrence of many, and some very heavy thunder-storms, and by three times the fall of rain of the corresponding month of 1853, we have still a less total deposition of ammonia over a given area, than in either May 1853, or in the average of the other months, the rain of which was experimented upon: and, with regard to the influence, on the other hand, of the minor aqueous depositions upon the amount of ammonia deposited, our notes and figures do not show any increase in the *actual amount* of ammonia so deposited, which could be attributed to them irrespectively of other circumstances, but rather that their more direct effect is upon the *proportion* of the ammonia to the generally less actual amount of water, as already pointed out. But, whilst the proportion of ammonia per million of the water collected is thus seen to depend more on the mere amount of the fall than on the period of the year, it must obviously at the same time be mainly influenced by the total amount of ammonia actually brought down over a given area; and this again would seem to have little direct or uniform connexion, either with the amount of the fall, or with the period of the year merely. Thus, as already stated, with three times as much rain in May 1854 as in May 1853, we have nearly the same, or even rather less total ammonia deposited, with the larger fall; and again, comparing the results of March and April 1853 with those of the same months of 1854, although it is true that in these cases we have the larger total amount of ammonia brought down with the larger fall of rain, it is seen that there is in March 1854 only one-seventh, and in April 1854 only one-fifth, as much actual ammonia deposited over a given area as in the corresponding months of 1853. It is then, as above alluded to, upon other circumstances than either the amount of the fall or the period of the year, that the amount of ammonia brought down by the aqueous deposits from the atmosphere mainly depends.

Turning to the more direct application of the figures to an important agricultural consideration, it may be stated that the amount of *nitrogen* which our experiments showed was brought down in actual solution from the atmosphere in the form of *ammonia*, was adequate to supply but a small proportion of the average annual amount of it contained in the produce of a continuously unmanured plot of ground. We must seek therefore for some other source of the nitrogen in our unmanured crops, than that which is brought down in rain, and in the minor aqueous deposits from the atmosphere, in the *form of ammonia:* and, without here entering into the question of the power of the soil, or of the plants themselves, to take up the ammonia or other nitrogenous compounds from the atmosphere, independently of the amounts which would be brought down in direct solution in water, there seems to be good ground for supposing, that another compound of nitrogen, namely *nitric acid*, is a more liberal supplier of nitrogen to plants from atmospheric sources, than even ammonia itself.

Although, as has been *already* mentioned, various experimenters have

detected nitric acid or nitrates in rain-water, yet it is to M. Barral that w
are indebted for the first quantitative estimations of nitric acid in rain wate
which could lead to the supposition, that this is probably an importan
natural or climatic source of supply of nitrogen available for the growth
plants: and scanty as it yet is, still our daily increasing knowledge as
the occurrence and properties of *ozone* tends to enhance the probability
such a view. It was hence a chief object of this investigation to determi
the quantities of the nitric acid as well as of the ammonia, in the rains c
lected at Rothamsted, and to estimate from these the sum of the nitrog
supplied by both, in relation to the average amount of it yielded in o
unmanured crops. Unfortunately, however, in consequence of the difficult
connected with the quantitative estimation of very small amounts of nit
acid, and especially owing to the existence of nitrogenous impurity in so
of the re-agents employed, though in proportions which for many purposes
analysis would be immaterial, the results arrived at on this head are by
means satisfactory or conclusive. or such as to justify a record of the num
rical results obtained.

The process adopted was as follows. Large quantities of the rain-wa
were evaporated with an alkaline carbonate several times to dryness, and t
solid residue was carefully collected and weighed after drying at 212°. T
per-centage of nitrogen in this solid matter was then sought to be det
mined by Dumas' direct-volume method of combustion with oxide of copp
Not only, however, were the results of duplicate analyses much more di
crepant than they should have been, but the actual amounts of nitrogen ind
cated were in some cases so exceedingly high, that suspicion was raised
to the purity of the re-agents employed; and it afterwards appeared, th
the oxide of copper, which had been prepared from the nitrate, was not fr
from compounds of nitrogen which yielded it up in the combustion. Bu
independently of the error which may have arisen from this cause, it mus
be admitted, that the process itself is not well calculated to attain the accu
racy requisite in such an investigation; and in fact, that an accurate metho
for the determination of small quantities of nitrogen, or rather of nitric acid
is still a great desideratum.

We repeat, then, that for the reasons stated, we refrain from recording th
numerical results yet obtained in regard to the amount of *nitric acid* in th
waters examined; nor can we with full confidence rely even upon thei
general indications, in the discussion of the important questions, with a vie
to the elucidation of which this investigation was chiefly undertaken, and t
which we still hope to recur on some future occasion. After these pr
cautionary observations, however, we may mention, that if the indications
our nitric acid determinations may be trusted at all, it would appear tha
whilst the per-centage and actual amount of ammonia might be less in th
rain of thunder-storms, and when there is a large fall of rain, the amount
nitric acid, on the other hand, is probably increased under the influence
storms. The results too would further lead to the conclusion, that the amou
of nitrogen brought down by the rain in the form of *nitric acid*, was co
siderable greater than that so deposited in the form of *ammonia*. On thi
point again, but without relying confidently on the indication, it may still b
interesting to observe, that with the very small amount of ammonia brough
down in the rain of the winter and spring months of 1853-54, so far as the
were examined, and which were succeeded by such an abundant harvest, th
nitric acid results, taking them as they stand, show a much higher amoun
than usual in the months in question. It is true, that a study of our M

teorological Tables is sufficient to show that other and more obvious and measurable climatic conditions materially conduced to such a favourable result.

In conclusion, since there can be no doubt, that nitrates, applied as manures, greatly enhance the growth of plants by virtue of the nitrogen they contain, any amount of nitrogen brought down from the atmosphere, in the form of nitric acid, must be considered to have an important influence on vegetation.

REPORT

TO

THE RIGHT HON. THE EARL OF LEICESTER,

ON

EXPERIMENTS CONDUCTED BY MR. KEARY

ON THE

GROWTH OF WHEAT UPON THE SAME LAND FOR FOUR SUCCESSIVE YEARS,

AT HOLKHAM PARK FARM.

By J. B. LAWES, F.R.S.

LONDON.

MDCCCLV.

FROM THE
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as been proved by careful experiments that wheat can be
n for several years in succession upon "heavy" land, and
by means of a proper supply of certain chemical substances,
verage or even full agricultural crop, according to the season,
be obtained each year with certainty. But it is believed
there have been no experiments of the same kind carried on
accuracy and on a large scale, upon soils other than those of
mparatively heavy character. It is, indeed, not many years
e the practice of removing from any land more than one
crop in succession, was condemned as bad in principle;
when we consider what was the amount of produce generally
ined in the second year, it must be admitted that, under the
mstances then existing, the practice could not be easily
ified. The increased sources, however, of artificial manures
ch have of late years been opened up, and more especially
comparatively large and cheap supplies of that valuable agent
nonia, have furnished the agriculturist of the present day
h a means of increasing, and in many cases of repeating, his
n crops, which was not possessed by his predecessor. To
se heavy lands on which root crops were considered but as a
essary evil, these comparatively cheap and abundant sources
ammonia may be considered almost as great a boon as the
plication of the four-course system to the light soils by the late
rl of Leicester. The limit, however, up to which the growth
corn by means of artificial manures may safely be extended
different descriptions of soil, has yet to be fixed by the aid
ier of practical experience, or of more direct experiment.

Leaving out of the question for the moment the important in-
nce of the subsoil in modifying the character and fertility of
erent descriptions of land, it may be said that, whilst in the
avy" soil certain elements of fertility are comparatively more
haustible, though capable of liberation in but small quan-
s each year,—in the "*light*" soil, on the other hand, there
generally a less store of the elements of fertility, though
will yield up more rapidly those which are added to
n in the form of manure. There is, however, an almost in-
te variety in the characters of our soils; in some parts of
island we have those of the most opposite description within
hort distance of each other; and there are some which so
bine the qualities of "light" and "heavy" land, as to render
ifficult on which side to classify them. There are others,
in, which are decidedly light in character so far as the surface
l is concerned, but which possess in their subsoil a vast store-
se of some of the native elements of fertility; and hence whilst

they are amenable to the same mechanical and other general management of the so-called light soils, they are more nearly allied to the heavy soils so far as the *native resource* of fertility is concerned. Whilst, then, a broad distinction must always exist between soils which can without injury be trodden by sheep in the wettest weather and those which under the same circumstances will scarcely bear a foot to be put upon them—and it may be convenient to apply to them the current designations of "*light*" or "*heavy*" accordingly—it must at the same time be remembered that these terms, as applied to a *surface-soil*, afford a very imperfect indication of the probable native resources, and consequently of the capabilities of growth without deterioration of the respective soils.

The soil upon which the experiments now to be recorded were made, is described by Mr. Keary as a "light, thin, and rather shallow brown sand loam," but "resting upon an excellent marl which contains a large quantity of calcareous matter." And he adds that he has invariably found these light sand loams *with the above subsoil* "to be most productive and grateful for *high farming*." In such a surface-soil, then, there will be combined the easily working qualities and the power of rapidly yielding up manurial matter of the so-called "light" soils; whilst in its subsoil, we have much of the native resource of constituents and probably the power of absorption or retention of manurial matter also, of the so-called heavy soils. Still it is of the greatest interest, both in a scientific and in a practical point of view, to ascertain by actual experiment how far those chemical substances which are employed with success for the increased growth of wheat upon heavy soils, can be used with advantage upon those of different descriptions: and these experiments are therefore of considerable value towards filling up one gap in our knowledge on this subject.

Here it may be suggested, that one very great desideratum at the present time is a few carefully-conducted experiments, not on too small a scale, to ascertain the result of the successive growth of wheat, on different descriptions of land, both unmanured and with a few well-selected artificial manures. How comparatively trifling would be the cost and trouble if one person only in each agricultural district in Great Britain would devote three acres of land in half-acre plots to the continuous growth of wheat for a series of years; one portion being always unmanured, one manured with farmyard dung, one with mineral manures only, one with ammoniacal salts only, one with both the minerals and the ammoniacal salts, and another with rape-cake? Yet such a simple series as this, carefully performed and accurately recorded, would in a few years furnish us with results *which would* be invaluable both in elucidating agricultural prac-

tices as they are, and in affording a sound basis for deduction, with a view to improvement according to the variations of soil and climate.

It may be well to mention, that with the exception of a suggestion as to the nature and amount of the manures to be applied, and the supplying of some of them from the quantities prepared for the Rothamsted experiments, these experiments at Holkham have been entirely under the management of Mr. Keary. That they have been conducted with extreme care and accuracy is, however, to those accustomed to make agricultural experiments upon a large scale, as obvious from the results recorded as if each operation had been witnessed. With a certain degree of experience it is impossible to be deceived in such matters; and it may safely be stated that it is the injudicious arrangement, the careless performance, and the inaccurate record of agricultural experiments, that more than anything else retard our progress in scientific agriculture at the present time.

It should further be remarked with regard to the land upon which these experiments were made, that previous to the introduction of the four-course system by the late Earl of Leicester, it had been considered too light for the growth of wheat. It has now for some years been farmed under that system; it was clayed about 12 years prior to these experiments, and the crop immediately preceding them was white turnips, manured with farmyard dung and guano, both tops and bulbs being drawn off the land. The experimental plots were half an acre each; the manures were as follows, and were all sown in the autumn, except No. 4, which was sown in spring:—

No. 1. Always unmanured.
No. 2. Mineral manures alone.
No. 3. Ammonia-salts alone; sown in the autumn.
No. 4. Ammonia-salts alone; sown in the spring.
No. 5. Both the mineral manure and ammonia-salts.
No. 6. Rape-cake.
No. 7. Farmyard dung.

The quantities per acre of the different manures are given in the Tables of the results which follow.

The *unmanured plot*, when once exhausted of the accumulations derived from the more recent previous manuring, will, of course, show the productive capability of the soil in a comparatively normal state, in conjunction with that of the annual climatic yield of the atmospheric elements of growth; and the results will provide a standard with which to compare the produce of the different manures.

The *mineral manure* employed, provides a liberal supply of the alkalies, alkaline earths, and phosphoric acid; and the produce it yields *compared with* that of the other plots, shows

whether the result of the cropping is to reduce the available supplies of such mineral constituents in the soil below that which is requisite to obtain the full benefit of the annual atmospheric supply of carbon and nitrogen, or whether it is the supply in the soil of the carbon or the nitrogen which is most exhausted.

The use of *ammoniacal salts alone*, which provide nitrogen for the growth of the crop, shows whether or not the latent mineral wealth of the soil is more than sufficient for the annual atmospheric supply of available nitrogen. And the object of sowing one plot with ammoniacal salts in the autumn and another in the spring, was to show whether it was practically advantageous to sow such soluble manures in the autumn in so light a soil.

The mixture of *both the minerals and the ammoniacal salts* shows, when the results are compared with those of each of these manures used separately—1st, whether or not the annually available native mineral supply of the soil, taken together with that in the manure, was not competent to a much greater amount of growth than the annual atmospheric supply of nitrogen was sufficient to produce?—and 2ndly, whether the amount of nitrogen supplied to the soil, when such a quantity of ammoniacal salts was used alone, was not in excess in proportion to the annually available supply of minerals from the soil itself?

Rape-cake contains a large proportion of carbonaceous and nitrogenous organic substances, and some mineral matter; and the nitrogen which was supplied in the quantity of it used was nearly identically the same, or perhaps rather greater in amount, than that in the ammoniacal salts of the other experiments.

The *farm-yard dung* employed, was the product of yards in which bullocks were fed on turnips, with a moderate quantity of oilcake. In this farm-yard dung, there would be added to the soil every year a larger supply of every constituent than was contained in the increased wheat crop grown.

In the three following Tables are given, the quantities of the different ingredients used as manure, and also the results obtained.

In Table I. are given—The amounts per acre each year on each plot, of the dressed corn, the offal corn, and the straw.*

In Table II. are given—The total produce of corn for the four years collectively, and of the straw for the last three years, of each plot; the average annual produce, both including and excluding the first year of the experiment; the total increase by manure of corn in the four years, and of straw in three years; the average annual increase by manure; and in the last column, the amount of corn yielded by each plot in the first year (1851) above the average of the succeeding years.

* It is much to be regretted that *the straw* was only weighed in the three last years, *and that* in no case is the weight of chaff and "colder" or "cavings" given.

TABLE I.

Showing the Quantities of Dressed Corn, of Offal Corn, and of Straw, per Acre, on each Plot in each Year.

No. of Experiment.	Manures per Acre per Annum.		Dressed Corn per Acre.								Offal Corn per Acre.								Straw per Acre.		
	Description.	Quantity.	1851.		1852.		1853.		1854.		1851.		1852.		1853.		1854.		1852.	1853.	1854.
		lbs.	bus.	pks.	bus.	pks.	bus.	pks.	bus.	pks.	bus.	pks.	bus.	pks.	bus.	pks.	bus.	pks.	lbs.	lbs.	lbs.
1	Unmanured	..	29	2½	15	2½	21	2	18	2½	0	3½	0	0½	0	0½	0	0½	964	1090	1240
2	Sulphate of Potash	200	34	2	19	0½	19	3	18	2½	0	3½	0	0½	0	1	0	1½	1542	1984	1574
	,, Soda	200																			
	,, Magnesia	100																			
	Super-phosphate of Lime (Calcined Bone-dust	200																			
	Super-phosphate of Lime (Sulphuric Acid	150																			
3	Sulphate of Ammonia	200	44	0	30	3	27	1	23	3½	1	2½	0	0½	0	1	0	1½	2276	2312	2122
	Muriate of Ammonia	200																			
4	Sulphate of Ammonia	200	41	0½	26	0	21	2	23	1½	1	1	0	0½	0	1	0	1½	2176	2760	1792
	Muriate of Ammonia	200																			
5	Sulphate of Potash	200	47	1	21	2½	29	2½	26	1½	1	0	0	0½	0	1	0	2	2410	2798	2307
	,, Soda	200																			
	,, Magnesia	100																			
	Super-phosphate of Lime (Calcined Bone-dust	200																			
	Super-phosphate of Lime (Sulphuric Acid	150																			
	Sulphate of Ammonia	200																			
	Muriate of Ammonia	200																			
6	Rape-cake	2000	52	0	28	1½	30	3	31	1	1	3½	0	1	0	0½	0	1	2598	2786	2656
7	Farmyard Dung	14 tons.	43	3½	31	0	30	2½	30	0	1	0	0	1	0	1	0	0	2420	2760	2599

TABLE II.

Showing the Total Produce of Corn for the Four years collectively, and of the Straw for the last Three years; the Average Annual Produce, both including and excluding the First year of the experiment; the Total Increase by Manure; the Average Annual Increase by Manure; and the amount of Corn yielded by each Plot in the First year (1851) above the Average of the succeeding years.

No. of Experiment.	Manures per Acre per Annum: Description.	Quantities.	Total Produce of 4 years' Corn and of 3 years' Straw. Dressed Corn, 1851-4.	Total Produce of 4 years' Corn and of 3 years' Straw. Offal Corn, 1851-4.	Total Produce of 4 years' Corn and of 3 years' Straw. Straw, 1852-4.	Average Annual Produce of Dressed Corn, 1851-4.	Average Annual Produce of Offal Corn, 1851-4.	Average Annual Produce of Straw, 1852-4.	Average Annual Produce of 1852-4. Dressed Corn.	Average Annual Produce of 1852-4. Offal Corn.	Average Annual Produce of 1852-4. Straw.	Total increase by Manure (Corn 4 years, Straw 3 years). Dressed Corn, 1851-4.	Total increase by Manure (Corn 4 years, Straw 3 years). Offal Corn, 1851-4.	Total increase by Manure (Corn 4 years, Straw 3 years). Straw, 1852-4.	Average Annual Increase by Manure. Dressed Corn, 1851-4.	Average Annual Increase by Manure. Offal Corn, 1851-4.	Average Annual Increase by Manure. Straw, 1852-4.	Total Corn in 1851 above the Average of ditto in 1852-4.
		lbs.	bus. pks	bus. pks	lbs.	bus. pks	bus. pks	lbs.	bus. pks	bus. pks	lbs.	bus. pks	bus. pks	lbs.	bus. pks	bus. pks	lbs.	bus. pks
1	Unmanured	..	93 1½	1 1½	3894	23 1½	0 1½	1298	17 3½	0 0½	1298	–	–	–	–	–	–	22 1½
2	Sulphate of Potash	300	91 3½	1 2	5100	23 0	0 1½	1700	19 0½	0 0½	1700	1 2½	0 0½	1206	0 1½	0 0½	402	16 0½
	,, Soda	200																
	,, Magnesia	100																
	Super-Phosphate of Lime (Calcined Bone-dust)	200																
	Super-Phosphate of Lime (Sulphuric Acid)	150																
3	Sulphate of Ammonia	200	125 2½	2 1½	6720	31 1½	0 2½	2240	27 0½	0 1	2240	32 0½	1 0	2236	8 0½	0 1	942	18 0½
	Muriate of Ammonia	200																
4	Sulphate of Ammonia	200	123 3½	2 0	6728	31 0	0 2	2243	27 2½	0 1	2243	30 1½	0 2½	2234	7 2½	0 0½	945	14 1½
	Muriate of Ammonia	200																
5	Sulphate of Potash	300	145 0½	1 3½	8515	36 1½	0 1½	2838	32 2½	0 1½	2838	51 2½	0 2½	4621	12 3½	0 0½	1540	15 1½
	,, Soda	200																
	,, Magnesia	100																
	Super Phosphate of Lime (Calcined Bone-dust)	200																
	Super Phosphate of Lime (Sulphuric Acid)	150																

Showing the Weight per Bushel of Dressed Corn; the Proportion of Offal Corn to the Dressed as 100; and the Proportion of Corn to Straw as 100.*

No. of Experiment.	Manures per Acre per Annum.		Weight per Bushel of Dressed Corn.					Proportion of Offal Corn to Dressed as 100.					Proportion of Total Corn to Straw as 100.*			
	Description.	Quantity.	1851.	1852.	1853.	1854.	Average.	1851.	1852.	1853.	1854.	Average.	1852.	1853.	1854.	Average.
		lbs.	lbs. ozs.	lbs. ozs.	lbs. ozs.	lbs. ozs.	lbs. ozs.									
1	Unmanured	..	63 14	59 12	62 0	62 0	61 14	2·21	0·80	0·58	1·12	1·40	97·6	79·3	86·2	86·0
2	Sulphate of Potash	300	63 10	59 12	63 0	63 8	63 7	2·54	0·23	1·26	1·68	1·63	74·3	63·5	76·1	70·7
	,, Soda	200														
	,, Magnesia	100														
	Super-phosphate of Lime { Calcined Bone-dust	200														
	Super-phosphate of Lime { Sulphuric Acid	150														
3	Sulphate of Ammonia	200	63 10	59 12	60 8	58 8	60 9	3·69	0·41	0·92	1·22	1·84	81·0	72·0	65·8	73·1
	Muriate of Ammonia	200														
4	Sulphate of Ammonia	200	63 8	58 0	61 0	58 0	60 2	3·00	0·41	0·79	1·61	1·61	75·0	70·2	76·9	73·5
	Muriate of Ammonia	200														
5	Sulphate of Potash	300	63 10	61 4	63 0	63 0	62 11	2·12	0·39	0·84	1·37	1·29	80·7	67·8	70·2	72·4
	,, Soda	200														
	,, Magnesia	100														
	Super-phosphate of Lime { Calcined Bone-dust	200														
	Super-phosphate of Lime { Sulphuric Acid	150														
	Sulphate of Ammonia	200														
	Muriate of Ammonia	200														
6	Rape-cake	2000	63 10	59 12	62 8	62 8	62 1	3·60	0·75	0·41	0·80	1·70	77·3	69·3	68·9	71·7
7	Farmyard Dung	14 tons.	63 8	60 8	63 8	64 0	62 14	2·28	0·81	0·82	0·00	1·11	77·8	70·3	73·9	73·8

* It must be remembered that the "Straw" does not include the Chaff and Colder or Cavings, which partly accounts for the very high proportion of Corn.

In Table III. are given—The weight per bushel of the dressed corn of each plot each year, and the average of the four years; also the proportion of offal corn to 100 dressed corn in each case; and the proportion of corn to 100 parts of straw.

It is seen in the Tables that the experiments have already extended over four seasons, namely, 1851-2-3-4. And although, owing to the variable effects of climatic agencies according to the nature of the manurial matters in the soil, and the stage or tendency of growth of the plant depending on it, and to the little that has yet been accomplished towards reducing the results of these complex influences within the rule and measure of calculation, it is highly important that such experiments should be conducted through a considerable series of years, so as to get a fair average, and thus to exclude the influence both of recent accumulations in the soil, and of the climate of individual seasons—nevertheless, the results of these first four seasons are of very considerable interest. And they can hardly fail to afford further proof to the practical farmer as to what are the constituents which, in the general course of agriculture with rotation and home manuring, and especially with a liberal growth of corn, are likely to be most exhausted, and which therefore it is most important to supply by artificial manures if he would increase his breadth and produce of corn.

The first point to call attention to in the Tables is the last column of Table II., where we have given for each plot the number of bushels of corn obtained in the first season of 1851, over and above the average of the three succeeding seasons. It is seen that there is in every case a larger produce, by 14 to 20 bushels, or even more, obtained by the same manure in the first year than in the average of the following years. This result speaks well for the previous "*condition*" of the land; and it is also very instructive as showing how useless, for the purposes of any general conclusions, are experiments with manures conducted over a single season only. It is in fact not until some of the elements of fertility, the due proportion of which to the others is comprehended in the term "condition," have been removed from the soil by the crop, that any safe deductions can be formed from the results of experiments with manures. Although it is possible that the field was not quite uniform as regards the accumulation from previous manures, it is at the same time not surprising that we should find the excess of produce in the first year greater on some of the plots than on the others, when it is remembered how very variable were the conditions of growth provided by the experimental manures, and also how different would be the progress or tendency of growth, and consequently the influence of the varying season, dependent on the varying supply of the elements of growth by manure. It is however very unfortunate that

the quantity of *straw* as well as corn was not ascertained in the first year; for it is exceedingly probable that had it been so, there would have been found to be a much greater uniformity in the excess of the *gross* or *total produce* of the first year over that of the others, than is observable in that of the produce of *corn alone*. We now proceed to a study of the results of the individual manures; and in the course of it it will be rendered pretty obvious what was the nature of the unexhausted matters of previous manuring, which gave this greater produce in the first year of the experiment.

Plot 1, which was unmanured, gave 39½ bushels of dressed corn the first year, 15½ the second, 21½ the third, and 16¾ the fourth; the average of the four years being 23¼ bushels, and that of the last three years nearly 18 bushels; which latter amount is nearly 22 bushels less than was obtained on the same plot in the first year. This average of 18 bushels per annum yielded after the condition of the land derived from recent previous manuring had been reduced by the first crop, is very nearly exactly that obtained annually on the much heavier soil of Rothamsted. This is a result which would scarcely have been anticipated; and it shows that, at any rate for the present, the annually available supplies of minerals in the soil are fully equal to the not very widely differing atmospheric resources of the two localities, as judged both by the results obtained, and by a comparison of the meteorological registries of the several seasons.

Plot 2, which was manured with salts of potash, soda, and magnesia, and super-phosphate of lime, gave 34½ bushels of dressed corn in the first year, rather more than 19 in the second, 19¾ in the third, and 18½ in the fourth. It is seen, therefore, that there is only a variation of about 1 bushel during the last three years; and that the average of these last three years is about 15 bushels less than was obtained in the first year. It is obvious that whatever were the elements of fertility present in the soil which were the source of the larger crop of the first year, they were in no way restored by the mineral substances supplied in the experimental manure. Again, comparing the produce of this mineral mixture with that of the unmanured plot, we find that taking the four years together there was actually rather more corn obtained without manure than by the minerals; the tendency of the latter being to increase the growth of straw, of which, taking the last three years together, there was about half a ton more obtained by means of the minerals. It is obvious therefore that mineral manures alone did little to remedy the characteristic exhaustion induced by the growth of the first crop of wheat, and that the annual mineral supplies of the soil were at any rate equal to the natural annual supply of nitrogen available for the growth of the crop.

In the next experiments (Nos. 3 and 4), the manure employed in each case consisted of 200 lbs. of sulphate of ammonia and 200 lbs. of muriate of ammonia per acre; but on Plot 3 they were sown in the autumn at the same time as the manures of all the other experiments, and on Plot 4 they were top-dressed in the spring. Looking to the columns of *total* produce (Table II.), we see that, taking the four years together, there is a difference of less than 2 bushels between the produce of the two plots, it being however rather in favour of the autumn-sown manure. The autumn-sown manure also gives on the average (see Table III.) a rather better weight per bushel. The produce of straw, taking together the three last years (it not being weighed in the first), is nearly identical in the two cases, there being a difference only of 8 lbs. in favour of the spring-sown manure. Upon the whole, then, the results are in favour of sowing these soluble manures in the autumn even in so light a soil. Comparing the produce of the different years by ammoniacal salts alone, we find that there is here again a fall in the produce of 18 bushels in the one case, and of 14½ in the other, from the first year to the average of the three last years; and that there is afterwards something like a gradual reduction from year to year. It is obvious, therefore, that the amount of nitrogen supplied in this large dose of ammoniacal salts is in excess over the annually available minerals of the soil, which it would appear are becoming gradually reduced. That these, however, are nevertheless considerably in excess over those required by the natural supplies of nitrogen, is obvious from the fact, that whilst by mineral manures alone we got no increase of corn whatever, and only a total increase of straw in the last three years taken together of about half a ton, the ammoniacal salts alone have given in the four years a total increase of 31 to 32 bushels of corn, and in the three last years of 2830 lbs. of straw. By the comparison, then, of the results of the mineral manures alone by the side of those of the ammoniacal salts alone, we have beautifully illustrated not only the nature of the characteristic exhaustion induced by the growth of the corn, but we are also able to form a pretty clear idea of the actual degree or extent of that exhaustion, much more so at any rate than we should be by any analysis of the soil.

In Experiment 5, we have in the manure both the minerals of Plot 2, which gave no increase of corn and but little increase of straw, and the ammoniacal salts of the Plots 3 or 4, which gave a considerable, though annually decreasing, amount of increase. The result of this mixture of both minerals and ammoniacal salts is to give, taking the 4 years together, from 53 to 54 bushels of corn and a large quantity of straw more than is yielded by the minerals alone. This, then, is an annual average of 13 to 14 *bushels of corn* and an equivalent of straw due to the ammoniacal

salts. And since there is in the 4 years about 20 bushels more increase by the mixture of both minerals and ammonia salts than by the ammonia salts alone, it is obvious that the minerals of this last 20 bushels of the total 53 of increase were derived from the mineral manures employed. This is, therefore, conclusive proof that these minerals were supplied to the land in a form capable of being rendered available for the growth of the plants; and it is therefore clear that the inability of the minerals when used alone, to increase the assimilation of organic constituents from natural sources, was not due either to their not containing soluble silica or other mineral matters required by the wheat-plant, or to an unavailable form of those constituents which were supplied.

In the next Experiment (No. 6), the manure consisted of 2000 lbs. of rape-cake per acre. As already explained, rape-cake contains a large amount of carbonaceous organic matter, a considerable quantity of nitrogen, and also some mineral matter. The quantity applied—namely, 2000 lbs.—was estimated to supply annually about the same amount of nitrogen (but in a different form of combination) as the ammoniacal salts in Experiments 3, 4, and 5 respectively. It also supplied as much of the more important minerals as would be contained in the *increase* of produce which was obtained by it. If, therefore, the total increase of produce obtained by the rape-cake should be pretty nearly the same as that yielded by the minerals and ammonia of No. 5, which contained, as has been said, nearly the same amount of nitrogen, but *no carbonaceous organic matter*, we can only conclude that the latter in the rape-cake has had little to do with the increase; and, in fact, that this is attributable to the supply of nitrogen and minerals afforded by the rape-cake. A comparison of the results obtained by the nitrogen and minerals of No. 5, and by the nitrogen, minerals, and carbonaceous organic matter of No. 6, shows that, taking the average of the 4 years, the latter gives about half a bushel per annum more corn, but about 90 lbs. less straw than the former. It is true that although the *average* produce of the minerals and ammonia of No. 5 and that of the rape-cake of No. 6 are so nearly identical, yet the produce of the two varies considerably in the individual years; but this can scarcely be wondered at, when it is remembered in what a very different form the nitrogen existed in the two manures, and also how differently the degree of their solubility, and consequently the stage or tendency of growth of the plant, would be influenced by equal conditions of climate. The average results are, however, as already stated, all but identical, and we are therefore justified in deciding that in this experiment, as well as in the former ones, the increase of produce was measured by the amount of nitrogen supplied by *the manure* in a form available for the

growth of the crop—provided, of course, the necessary minerals were not absent; and, further, that the carbonaceous organic matter is of itself of no practical utility as a manure for wheat. It may be mentioned that this is a result precisely similar in character to that which has been obtained in the Rothamsted experiments.

The next and last Experiment is No. 7, in which 14 tons of farm-yard manure were applied per acre annually. It has already been stated that this amount of farm-yard dung would supply more of every constituent than would be contained in the increase of crop due to its employment. It would contain, in fact, from 3 to 4 tons of carbonaceous organic substance, whilst the annual increase of produce did not contain 1 ton of such matter. The minerals in the dung would also very far exceed those in the increased produce yielded, and its nitrogen would be greater in amount than that supplied in the ammoniacal salts of Experiments 3, 4, and 5, or in the rape-cake of Experiment 6. There would, however, be this difference as regards the nitrogen—namely, that whilst that which was supplied in the ammoniacal salts would be the most readily dissolved in the soil, that in the rape-cake would be so in a less degree, though much more rapidly in a light soil than in a heavy one. Part of the nitrogen of the dung too would also be rendered easily available, but that portion which entered into the composition of the straw would probably require some years before the whole was liberated and applicable for the growth of the crop. The result of the experiment with the dung is, that we get an average annual increase by it of about 10½ bushels of corn and 1300 lbs. of straw, which is less by nearly 3 bushels of corn and about 150 lbs. of straw than was obtained by the rape-cake. The weight per bushel of the corn grown by the dung was, however, on the average about ¾ lb. heavier than that by the rape-cake, which will account for part of the deficiency. Now, as we have seen by the other experiments, that neither minerals alone nor carbonaceous organic matter, had any influence in the increase of the crop, but that wherever there was a supply of nitrogen in the manure there was always a very considerable increase, we have every reason to conclude that it was the amount of nitrogen liberated from the dung in a form applicable by the plants which fixed the limit to the increase of produce obtained by its use. And in confirmation of this conclusion, it may be recalled to mind how very small would be the amount, both in the carbonaceous organic matter and of mineral matter, in the increase of produce obtained in proportion to the amount of either of them supplied by the farm-yard manure. It is true, that neither is the amount of *nitrogen* contained in the increased produce of wheat ever equal *to that supplied* in the manure which yielded that increase; but

it must be remembered that, besides any liability to loss by drainage, to which all might be subject, the nitrogen, in several of its forms of combination, is also volatile, and may be exhaled into the atmosphere and lost, but this is not the case with the mineral constituents of manure.

Upon the whole, then, a careful study of the various experiments has proved,—

That the soil, even with the most unusual and very exhausting process of carrying off the land the total grain and straw of several successive corn-crops, after a root-crop which had also been drawn from the land, still contained a larger annual available supply of minerals than the annual natural supplies of other constituents, nitrogen or carbon, were adequate to turn to account;—

That the excess of the annual supply of minerals in the soil over that required to appropriate the natural resources of nitrogen, is proved, by the effects of ammoniacal salts alone, to have been equal to the further growth, during 4 years, of about 32 bushels of wheat, or an average of about 8 bushels per annum;—

That beyond the increased annual produce which the supply of minerals in the soil was adequate annually to provide when nitrogen was not wanting, the average capabilities of the climate were competent for the maturing of a still greater produce, if additional minerals as well as the ammoniacal salts were provided; and, in that case, from once and a half to twice as much corn was grown as the natural supplies of nitrogen, even with a most liberal supply of minerals, were sufficient to produce;—

That carbonaceous organic matters (such as are contained in rape-cake and farm-yard dung) are of themselves of little or no effect in increasing the growth of wheat.

We can now have little difficulty in deciding to what accumulated elements of growth to attribute the higher "*condition*" or *greater fertility* of the first year, as compared with the succeeding ones. Mineral manures alone have had no effect in restoring the fertility which was exhausted by the first experimental crop. Ammonia alone gave a produce of several bushels more than the unmanured plot in the first year, and has, on the average of the last 3 years, given half as much again of produce as either the unmanured or the mineral manured plot; and the addition of minerals to this ammonia has restored a further increment of the lost fertility. In no case, however, have the artificial manures of subsequent years entirely restored the original fertility: or rather, in no case (with it is true a difference of season), has there since been a produce quite equal to that of the unmanured space of 1851. From the above facts it is obvious that in the first year there existed in the soil a larger supply both of available minerals and of available nitrogen than in any of the succeeding years; *but that in* the first year there existed accu-

mulated available minerals in the soil *considerably in excess* of the accumulated *nitrogen* available for the growth of the crop; and that it was the limited amount of the latter, and not of the former, which fixed the limit to the amount of produce of the unmanured plot in the first season—that is, so far as the greater amount of it that year was due to manurial constituents independently of the climatic variations of the different seasons. In a word, the practical fact is elicited, that by the growth of corn in a soil which has been cultivated in an ordinary manner with rotation and home-manuring, the supplies of available minerals are not nearly so soon exhausted as those of the available nitrogen. In fact, the soil has been reduced from a comparatively *high wheat-growing condition* to a very low one, by the exhaustion of its immediately available floating stock of nitrogen; and it was in this very *low wheat-growing condition*, notwithstanding that the mineral elements of fertility still existed in it in such an excess in relation to the natural resources of nitrogen, as was sufficient for an increase of crop during a succession of years, provided only that *nitrogen* was artificially added to it.

What, then, is the lesson to practical farming which these experiments should teach us? It will not be supposed, that because it is here shown that in a cultivated soil of a comparatively light character an increased growth of wheat may be obtained over a continuous series of years by the use of nitrogenous manures alone—that hence rotation and home-manuring should be abandoned, and that corn-crops should be grown continuously by means of nitrogenous artificial manures? There cannot, however, be a doubt of the legitimacy of the inference from these and other experiments, that provided the land receive in a course of years a due share of the home manures derived from feeding of horses and other stock on the farm, the mineral supplies of the soil will be amply sufficient to sustain an increased and even repeated growth of corn, by means of nitrogenous artificial manures, considerably beyond that which is recognised by the leases or the current practices of the day; and a further assurance that the necessary minerals are not likely to become deficient, under the judicious adoption of such an increased growth of corn, is to be found in the fact that there are few really large sources of nitrogenous manures which do not, at the same time, bring upon the land a considerable amount of some of the more important minerals also.

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REPLY

TO

BARON LIEBIG'S

RINCIPLES OF AGRICULTURAL CHEMISTRY."

BY

J. B. LAWES, F.R.S., F.C.S.

AND

DR. J. H. GILBERT, F.C.S.

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ON

SOME POINTS CONNECTED

WITH

AGRICULTURAL CHEMISTRY.

nore than one occasion we have expressed our high sense
ıe important services rendered to the furtherance of fixed
:iples in agriculture by Baron Liebig. We have particu-
called attention to the fact that the masterly review of
then existing knowledge on the subject contained in his
: entitled "*Organic Chemistry in its Applications to Agri-
re and Physiology*," and published in this country in 1840,
more than any other circumstance, given that stimulus and
tion to chemical inquiry, in connexion with agriculture,
h has characterised the subsequent period. It was naturally
) expected, however, that the evidence to be derived from
nquiry that had thus been incited, would, in the progress of
, necessitate the modification or extension of the expression
given to the relations of science with practice.

his third edition, indeed, published in 1843, Baron Liebig
elf announced, in his Preface, that he had, in the years
h had elapsed between that edition and his first, endea-
ed to make himself "acquainted with the condition of prac-
farming, and with what it requires, by a journey through
gricultural districts of England and Scotland"—and also in
interval instituted a long series of experiments on the subject
ıe laboratory at Giessen, with the sole object of giving a
ır basis to his "exposition of the causes of the advantageous
ts attending the practice of rotation of crops, and also of

effectually banishing all doubts concerning their accuracy." He goes on to say, "*I am now, for the first time*, since the completion of these labours, in a situation to give a simple and determinate expression to my views of the origin of animal excrements, and of the cause of their beneficial effects on the growth of all vegetables." And he adds: "*Now that the conditions which render the soil productive, and capable of affording support to plants, are ascertained*, it cannot well be denied, that from chemistry alone all further progress in agriculture is to be expected."

After this announcement, it would have been unfair to Baron Liebig, to have attributed to him in any discussion, the views of his earlier editions, on points wherein he had modified them in his later ones. With this feeling, whenever we have, in our various papers, pointed out wherein it appeared to us that Baron Liebig's doctrines, as applied to *agriculture as it is*, required either modification or correction, we have invariably discarded all reference to his earlier published views, and assumed as our starting-point those given in his later editions, for which he claims a firmer basis and a greater certainty.

Baron Liebig, however, as it would appear, without having at that time read our own statement of our views, but only that summary of them given in a few lines by the late Mr. Pusey, devoted, in his 'Letters' published in 1851, a note of some pages to a notice of our conclusions as so given. He expressed himself thus:

"With regard to the experiments of Mr. Lawes (the best authority, according to Mr. Pusey), they are entirely devoid of value, as the foundation for general conclusions. With a knowledge of our experience of the effects of fallow, and of production on the large scale, it requires all the courage derived from a want of intimate acquaintance with the subject to assert, that *certainly* ammonia is peculiarly fitted for *grain*, and *phosphorus* for *turnips*, and that manuring with straw is *probably* advantageous for turnips."—*Letters*, 3rd edition, p. 480.

Now, although Mr. Pusey was, perhaps, more competent than any other practical agriculturist to speak to the wants of British farming, yet the terms used by him were by no means those which we ourselves should have employed; and it was obviously unfair in any writer to take his statement of our views, rather than that which we have ourselves given of them.

But, nevertheless, so fully satisfied were we of the conclusions intended to be expressed by Mr. Pusey—*in the language and in the connexion in which we have ourselves given them in our Papers*—that we felt it incumbent on us to reply to such emphatic condemnation of our experiments and conclusions, by one whose opinion, if founded on fair and careful criticism, should have so much weight as that of Baron Liebig. Hence

it was that, in 1851, we published in this Journal, in a Paper entitled '*Agricultural Chemistry, especially in relation to the Mineral Theory of Baron Liebig*,' an answer to his strictures above referred to.

It is in reply to our Paper, just mentioned, that Baron Liebig, in the spring of the present year, published a short treatise entitled "*Principles of Agricultural Chemistry, with special reference to the late Researches made in England*," which has been circulated very freely in Germany, France, England, and America. Nearly the whole of this treatise is devoted to a critical examination, in some form or other, of the experiments made at Rothamsted—of the opinions to which, by these and facts relating to other districts, we have been led—and of our representations of the author's views, as distinguished either from the expression which he claims himself to have given to them in his former works, or from that which he would at present assign to them. He accuses us at once of *not having read*, of *misunderstanding*, and of *misstating* his views. He asserts that we have *disproved* that which we intended to *prove;* that we have *proved* that which we intended to *disprove;* and, in fact, that *our results in all points confirm the truth of his doctrines*, as announced in his works.

These are certainly rather serious charges. But not only have they been made under the incitement of controversy, by Baron Liebig himself, but they have been deliberately endorsed, in a Preface, by Professor Gregory, the English editor of Baron Liebig's work, in a manner so inconsistent with the obvious facts and justice of the case, that one can hardly be otherwise than amused at the zealous partisanship which could alone account for his extraordinary assurances. But this is not all. Periodicals, unconnected either with chemistry or agriculture, have, upon the credit of the high authorities referred to, taken for granted the truth of their statements; and thus they have been echoed, unexamined, through the general press. It is only due, therefore, both to ourselves, and to the large body of intelligent agriculturists who have from time to time expressed their confidence in the conclusions emanating from Rothamsted, and who have in so marked a manner acknowledged their sense of the value of the experiments upon which they are founded, that we should fully vindicate, not only the opinions themselves, but our integrity and honour in dealing with those of others, which have thus been called in question in high quarters.

We cannot but regret, on many grounds, that it should have become necessary to treat of our important subject much more in the controversial form than we had at first designed. It will, however, be our endeavour to turn the course which has thus been forced upon us to as good account as possible, by

making the execution of this part of our task the occasion of bringing before our readers a review of the published views, not only of Baron Liebig and ourselves, but of distinguished authorities both in this country and abroad, who have pronounced on the points involved.

The plan we propose is as follows:—

1st. To show, by copious quotation, both from Baron Liebig's previous writings and our own, what really have been the published opinions and doctrines of the former, and how far our own statements of those opinions and doctrines are justified by his own words.

2nd. To show how his views have been understood and interpreted by other writers than ourselves, not only in this country, but in Germany, France, and America.

3rd. To examine Baron Liebig's statements and criticisms of our experimental evidence and conclusions regarding the growth of *wheat* and *turnips;* and to adduce further evidence and arguments in support of the conclusions which we really have maintained on the points involved.

4th. To illustrate, by condensed summaries of an immense mass of experimental results, some prominent points of interest connected with the *action of manures on the different crops of rotation*, and with the chemical circumstances involved in *fallowing*, and a *rotation of crops itself.*

And lastly, throughout our observations we shall take occasion to point out the material admissions which are to be discovered in the newly published opinions of Baron Liebig; which show, that, notwithstanding there are still points of difference between us, we have now at least the sanction of his almost unequalled sagacity for the judgment which we have pronounced on certain points, as distinguished from the opinions which he formerly so prominently advocated on the same.

Firstly, then, as to the consistency of our statements of Baron Liebig's doctrines, with his own statements of those doctrines. One of his chief complaints against us on this head, is in reference to a sentence occurring in one of our Papers; which we quote it below. But we must here call attention to the inaccurate manner in which Baron Liebig makes his quotations; not only in the case immediately under consideration, but in many others, some of which we shall have occasion to point out. A similar want of accuracy is observable in his quotations both from Professor Wolff and Mr. Way, in the course of this same controversy. The portion which we give in brackets, thus [ ],

urs in the original, but is not given by Baron Liebig in his arently continuous quotation from our Paper.

In the course of this inquiry, the whole tenor of our results [*and also of rmation, derived from intelligent agricultural friends, upon every variety nd in Great Britain*] has forced upon us opinions different from those of fessor Liebig on some important points; and more especially in relation to so-called 'mineral theory,' which is embodied in the following sentence, e found at page 211 of the third edition of his work on Agricultural mistry, where he says, 'The crops on a field diminish or increase in exact portion to the diminution or increase of the mineral substances conveyed t in manure.'"—*Journal of the Royal Agricultural Society of England*, xii. part i. p. 2.

With regard to the omission made by Baron Liebig in his quo-ion, we will only here observe how important is such an omis-n, when one of the main objections which Baron Liebig alleges inst our conclusions is, that they are founded upon *our own eriments alone*, and without any consideration of what would pen *on other soils and in other localities!*

Baron Liebig complains that the sentence which we have ted as embodying his own doctrines, has been detached m its natural connection with a series of sentences, and thus neaning given to it quite different from that intended by author. In proof of this, he professedly gives the sentence uestion with its context, and also comments, to which we ll call attention. But here again we must beg the notice of reader to Baron Liebig's inaccurate mode of giving a quotation, the purposes of controversy, within unbroken inverted commas. e give the sentence, from p. 210 of the 4th edition of Baron big's '*Chemistry in its Applications to Agriculture and siology*,' from which he himself professes to quote. The t *two* portions which we give between brackets, thus [ ], ur in the original, but are omitted in Baron Liebig's quotation; l the word "*the*" so inclosed, is given in the quotation, but es not occur in the original :—

'Hence it is quite certain, that in our fields the amount of nitrogen in the ps is not at all in proportion to the quantity supplied in the manure, and t [*the soil cannot be exhausted by the exportation of products containing rogen* (*unless these products contain at the same time a large amount of neral ingredients*), *because the nitrogen of vegetation is furnished by the osphere and not by the soil. Hence also*] we cannot augment the fertility our fields [*or their powers of production*], by supplying them with manures h in nitrogen, or with ammoniacal salts alone. The crops on a field minish or increase in exact proportion to the diminution or increase of the neral substances conveyed to it *in* [*the*] *manure*."

The reader will perceive more clearly, as we proceed, the portance of the omissions made in the quotation of the ove sentence, bearing, as they do, both upon the question of hat were Baron Liebig's opinions as to the dependence of

plants upon the *atmosphere*, and *not upon the soil*, for their nitrogen in *agriculture* as distinguished from normal vegetation—and upon the distinctions which he seeks to draw, between *fertility* (as implying duration) and *immediate production* merely.

But upon the sentence in the altered form, Baron Liebig says:—

"In the sentences just quoted from my book, the produce of the land is compared with the proportion of nitrogenous matter, inclusive of mineral substances, supplied *in the manure*, and with the amount of mineral constituents, inclusive of nitrogenous substances, supplied *in the manure*.

"The words '*by ammoniacal salts alone*' and '*in the manure*' show that I never thought of excluding carbonic acid and ammonia in the manure. According to Mr. Lawes's mistaken notion of my meaning, I ought to have said, omitting the word *manure*, that '*on the contrary the fertility of the land rises and falls with the amount of mineral substances supplied to it.*' But this I have not said.

"The meaning of these sentences in my work is this: '*that ammoniacal salts alone*' *have no effect; that, in order to be efficacious, they must be accompanied by the mineral constituents, and that the effect is then proportional to the supply, not of ammonia, but of the mineral substances.*"—*Principles of Agricultural Chemistry* p. 54, 55.

Now, in reference to Baron Liebig's third paragraph of comment, it may be observed that, inasmuch as in the original he speaks of "manures *rich in nitrogen*," as well as "ammoniacal salts *alone*," the statement that he meant merely "*that ammoniacal salts alone have no effect*," is obviously quite inadmissible; whilst the introduction of the definite article "*the*" is the only foundation for the meaning claimed by Baron Liebig that he only included manure containing both nitrogenous matter and mineral substances—and that he did not speak of the fertility of the land rising and falling "with the amount of the mineral substances supplied to it." But he himself admits in another page (*Principles*, 115) that he *did* refer to manure generally, whether "*mineral* manure, guano, poudrette, farmyard manure, &c."

Whatever may have been the meaning of Baron Liebig in the sentence we have quoted, or whatever the interpretation which he would now give it, we shall presently make such full quotation from the same edition of his work, and from other publications, and also from other authorities, as will enable the reader to judge for himself—not only what was the obvious meaning of the sentence in question, but what has been the interpretation of that sentence, taken in connection with many others in his writings, by others of his readers than ourselves.

Before doing this, however, we will give a single illustration of how fundamental was the change made by Baron Liebig from the first edition of his work, to the third and fourth and subsequent publications; as by this means, the reader will not only be prepared to form a right judgment of what we shall have after-

wards to quote, but the unscrupulous unfairness of an anonymous article in the Journal of the Highland Society will be fully apparent. We have already shown how distinctly, in the Preface to his third edition, Baron Liebig admitted a change and perfecting in his views since the first. And yet, incredible as it may appear, our Northern critic admittedly makes his quotations by which to fasten the accusation of misrepresentation upon ourselves, from Baron Liebig's *first* edition, and from his 'Principles,' lately published *in the course of the controversy!*

One of the quotations made by this critic, with a view of showing that we have misrepresented Baron Liebig, in attributing to him an inadequate appreciation of the importance of available nitrogen *within the soil itself* for the growth of some of our most important crops in *agricultural quantity*, he takes from the *first* edition, as given below. We give by its side the sentence as it occurs in Baron Liebig's *third* and *fourth* editions; and the capitals are our own, to draw attention to the words altered from the earlier edition to the later ones.

"Cultivated plants receive the same quantity of nitrogen from the atmosphere as trees, shrubs, and other wild plants; BUT THIS IS NOT SUFFICIENT FOR THE PURPOSES OF AGRICULTURE."—*1st Edition*, p. 85.

"Cultivated plants receive the same quantity of nitrogen from the atmosphere as trees, shrubs, and other wild plants; AND THIS IS QUITE SUFFICIENT FOR THE PURPOSES OF AGRICULTURE."—*3rd and 4th Editions*, p. 54.

Notwithstanding, then, that in his third and fourth editions, Baron Liebig exactly reverses the opinion held in his first, on the very point in reference to which the sentence is brought against us—yet it is from the *first* edition that our critic quotes! In this *slight* alteration, too, we have a key to the fundamental change in Baron Liebig's views in regard to the capability of a liberal supply of the constituents proper to the soil itself—*the mineral constituents*—to enable plants to obtain from the atmosphere "*sufficient*" nitrogen for an *agricultural* amount of crop.

We shall now assume that we have given evidence enough of a change in Baron Liebig's views from his first edition to his later ones, to show that it is quite inadmissible to quote from his *earlier* in judgment of our representations of his *later* opinions. The following is the manner in which we have ourselves represented those opinions in reference to the point referred to by the critic in the *Highland Society's Journal*, and also by a writer in the *Saturday Review* of November 10, 1855, *et seq.*:—

"*Practical agriculture consists in the artificial accumulation of certain constituents to be employed either as food for man or other animals, upon a space of ground incapable of supporting them in its natural state.* This definition of agriculture is, I think, important, as distinguishing English agriculture at least, from the system pursued in various parts of the world, where the population is small and the land of little value, viz., of taking only the natural

produce of the soil, without any effort to increase it, and in time abandoning it for a soil as yet undisturbed. If Liebig had sufficiently considered this distinction, he would not have assumed that certain substances employed as manures are of little value, because plants and trees, in their natural state, are capable of obtaining them in sufficient quantity for their use."—*Journal of the Royal Agricultural Society of England*, vol. viii. part i. p. 227–8.

"The atmosphere and the virgin soil being originally the exclusive sources, the former of the '*organic*,' and the latter of the '*inorganic*' or '*mineral*' constituents of plants, it has been supposed that the amount of produce which a given space of ground would yield must depend upon its richness in those substances proper to itself, namely, the mineral constituents; and that these being supplied in full quantity, according to the indications of the analyses of the ashes of the crops it is wished to grow, the atmosphere would always prove an ample available resource for the more peculiarly vegetable matters. It will be readily understood that on such a view as this, economy in agriculture would be attained by a very different course of practice from that required were it to be shown that cultivation should effect an artificial accumulation in the soil of those constituents primarily derived from the atmosphere, rather than of such as more especially belong to its own constitution.

"The theory referred to has led to the analysis of the ashes of a great many agricultural crops, and upon the data thus obtained (rather than upon a consideration of the requirements actually induced by an artificially enhanced vegetation, or of the real source and destination of the constituents under a course of practical agriculture), recommendations to the agriculturist have been founded, the validity of which it was desirable should be tested by actual experiment, as well as by the presumed dictates of experience."—*Ib.* vol. viii. part ii. p. 535.

"It is true that, in the case of vegetation in a native soil, unaided by art, the mineral constituents of the plants being furnished from the soil, the atmosphere is found to be a *sufficient* source of the nitrogen and carbon; and it is the supposition that these circumstances of *natural vegetation* apply equally to the various crops when grown under *cultivation* that has led Baron Liebig to suggest that, if by artificial means we accumulate within the soil itself a sufficiently liberal supply of those constituents found in the ashes of the plant, essentially soil constituents, we shall by this means be able in all cases to increase thereby the assimilation of the vegetable or atmospheric constituents in a degree sufficient for agricultural purposes. But agriculture is itself an *artificial* process; and it will be found that, as regards the production of wheat more especially, it is only by the accumulation within the soil itself of nitrogen, *naturally* derived from the atmosphere, rather than of the peculiarly soil-constituents, that our crops of it can be increased. Mineral substances will indeed materially develop the accumulation of vegetable or atmospheric constituents when applied to *some* of the crops of rotation; and it is thus chiefly that these crops become subservient to the growth of the cereal grains; but even in these cases it is not the constituents, *as found collectively in the ashes of the plants to be grown*, that are the most efficient in this respect; nor can the demand which we find thus made for the production of crops in *agricultural quantity* be accounted for by the mere idea of supplying the *actual* constituents of the crop. It would seem, therefore, that we can only arrive at correct ideas in agriculture by close examination of the actual circumstances of growth of each particular crop when grown under cultivation."—*Ib.* vol. xii. part i. p. 6, 7.

But there is another sentence in one of our Papers in which we have sought to indicate Baron Liebig's views, against which he strongly protests. It is as follows:—

"In conclusion, then, if the theory of Baron Liebig simply implies that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up, we fully and entirely assent to so evident a truism; but if, on the other hand, he would have it understood that it is of the mineral constituents, as would be *collectively* found in the ashes of the exported produce, that our soils are deficient relatively to other constituents, and that, in the present condition of agriculture in Great Britain, 'we cannot increase the fertility of our fields by a supply of nitrogenized products, or by salts of ammonia alone, but rather that their produce increases or diminishes, in a direct ratio, with the supply of mineral elements capable of assimilation,' we do not hesitate to say that every fact with which we are acquainted, in relation to this point, is unfavourable to such a view."—*Ib.* vol. xii. part i. p. 39.

The comments Baron Liebig makes on this sentence are as follows:—

"In the first part of this quotation Mr. Lawes *admits the truth of the so-called mineral theory;* in the second I find *two erroneous statements the continued diffusion of which I can no longer tolerate.*"—*Principles*, p. 115.

In the first part, then, of this comment by Baron Liebig, we have the important admission, that the so-called "Mineral Theory" —*as he would now have it understood*—"simply implies that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up." And if it should be shown by the copious quotations which we have yet to make from Baron Liebig's former writings, that his *earlier* "Mineral Theory," and as applied to *agriculture*, was far more correctly indicated by the latter portions of our sentence, which Baron Liebig tells us he "can no longer tolerate"—if this be shown, we may congratulate ourselves on a very material limitation of his formerly promulgated opinions. We have here also the admission, that "*we* fully and entirely assent" to such a "Mineral Theory," as "simply implies that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up." And in this latter admission Baron Liebig must surely be conscious of a rebuke to himself, for the pervading insinuation throughout his criticism of our views, that we have ignored the necessity of mineral constituents to plants. Thus he says—

"It is not easy to understand how Mr. Lawes could deduce from his results the conclusion '*that nitrogenized manures are peculiarly adapted for the culture of wheat*,' since such manures can only produce a favourable result if certain *preliminary conditions*, which Mr. Lawes has entirely disregarded, be fulfilled." —*Ib.* p. 79.

And again—

"Now, every one would suppose from this, that Mr. Lawes thought that the use of ammonia enabled us to dispense with that of mineral manure, founded on the knowledge of the composition of vegetable ashes, and that these, the ashes or mineral constituents, might be replaced by ammonia." . . .

"For if Mr. Lawes admit, that the mineral constituents are indispensable to plants, how can he maintain that these very mineral constituents are replaceable by ammonia, that is to say, that by means of ammonia we can altogether dispense with them?"—*Ib.* p. 89.

Baron Liebig is perfectly well aware, that the sentences he refers to, presupposed certain "*preliminary conditions*," and had reference simply to the *source* of the mineral constituents of plants in the ordinary course of agriculture. For those who have not read our Papers, however, we may say, that any such insinuation as that here intended by Baron Liebig, is emphatically condemned—not only by special sentences, such as those quoted above, but by the whole tenor of our writings—as Baron Liebig himself is well aware, if ever he have read them.

But to return to Baron Liebig's comments on that statement of his doctrines which he "can no longer tolerate," he says:—

"The concluding sentence ascribes to me the assertion that the produce of land is proportional to the supply or diminution of the available mineral constituents. *This I have never said.*"—*Ib.* p. 115.

Compare this with the quotation already given:—

"The crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure."—*Agricultural Chemistry*, 3rd ed., p. 212.

Again Baron Liebig says:—

"With regard to the previous sentence, I find in my work only one passage in which I speak of the land of England in the sense understood by Mr. Lawes."—*Principles*, p. 115.

And in reference to this point he also says:—

"It is not difficult to refute the opinions of another, if we ascribe to him assertions which he has never made.

"It never occurred to me to assert that the land of Great Britain was deficient in the substances which are found together in the ashes of the crops raised on it, or that, on a soil naturally fertile, rich crops might not be obtained for several successive years, *by the use of ammoniacal salts alone.*"—p. 116.

Baron Liebig denies, then, that he has addressed himself to the *resultant wants of agriculture as practised in Great Britain*—that he has ever maintained that the fertility of our fields *increases or diminishes in a direct ratio with the supply of mineral elements capable of assimilation*—or that, it is *in the mineral constituents, as collectively found in the ashes of the exported produce, that our soils are deficient relatively to other constituents.*

We will now examine the foundation of these several assertions. And first—in order to show, that it was not only AGRICULTURE (as distinguished from normal vegetation), but that it was *agriculture*

as practised in Great Britain, on which Baron Liebig has addressed the English public in his various writings, we say:—

That the title of one of his publications is—'Organic Chemistry *in its Applications to Agriculture* and Physiology.'

That of another is—'An Address to the Agriculturists of Great Britain, on the Principles of *Artificial* Manuring.'

And of another—'On *Artificial* Manures.'

That in the preface to the third and fourth editions of his main work, he states them to be put forth, after having endeavoured to make himself "acquainted with the condition of practical farming, and with what it requires, by a journey through the agricultural districts of England and Scotland."

We were justified then in concluding that Baron Liebig put forth his doctrines not only as applicable to *normal vegetation*, but to *agriculture*, and to the existing condition and wants of agriculture as practised in *Great Britain*. We will now show, by quotations from his works, whether we have mis-stated his views on the following important points, viz.:—

The dependence of our *cultivated* plants—whether graminaceous or leguminous—upon *atmospheric sources* for their supply of nitrogen.

The direct dependence of the *amount of produce* on the available *mineral* food of plants within the soil.

The nature of the restitution to be made "*from without*" in a course of practical agriculture.

He says (4th edition, as already quoted):—

"Cultivated plants receive the same quantity of nitrogen from the atmosphere as trees, shrubs, and other wild plants; and this is *quite sufficient for the purposes of agriculture.*"—p. 54.

"It is obvious, therefore, that there is no deficiency of atmospheric food for the plants of these regions, *and there can be none for our own cultivated plants.*"—p. 167.

"Are the fields of Virginia, the fields of Hungary, *our own cultivated plants*, not able to receive it from the same sources as the wild-growing vegetation? Is the supply of nitrogen in animal excrements a matter of *absolute indifference?* OR DO WE OBTAIN IN OUR FIELDS A QUANTITY OF THE CONSTITUENTS OF THE BLOOD, ACTUALLY CORRESPONDING TO THE SUPPLY OF AMMONIA?"—p. 205. The capitals are Baron Liebig's own.

"Hence it is quite certain, that *in our fields*, the amount of nitrogen in the crops is not at all in proportion to the quantity supplied in the manure, and that the soil cannot be exhausted by the exportation of products containing nitrogen, (unless these products contain at the same time a large amount of mineral ingredients), *because the nitrogen of vegetation is furnished by the atmosphere, and not by the soil.*"—p. 210.

"Is fertility not quite independent of the ammonia *conveyed to the soil?* If we evaporated urine, dried and burned the solid excrements, and supplied to our land the *salts of the urine, and the ashes of the solid excrements*, would not the cultivated plants grown on it—the *gramineæ and leguminosæ*—obtain their carbon and nitrogen from the *same sources* whence they are obtained by the gramineæ and leguminosæ of our meadows? *There can scarcely be a*

doubt with regard to these questions, when we unite the information furnished by science to that supplied by the practice of agriculture."—p. 203.

These then are Baron Liebig's opinions, in his later editions, as to the equal independence of plants—wild or cultivated—graminaceous or leguminous—of assimilable nitrogen provided *within the soil*. We do not mean to say, that there are not both facts and opinions recorded in Baron Liebig's writings, totally incompatible with the series of sentences which we have quoted, or have still to quote. We leave the inconsistency to be explained by Baron Liebig himself.

We must here beg the reader's attentive recognition of the fact, that the subject of which both Baron Liebig and ourselves are speaking is *agriculture*, not normal vegetation—that we treat of "*cultivated*" land, not a mere sand-pit, or other circumstances (*agriculturally* speaking abnormal), under which every mineral constituent of the plant has to be artificially provided. It must not be forgotten that there are here certain "*preliminary conditions*," namely, a *cultivated soil*—one, therefore, which is supposed to contain a certain amount of the necessary food of plants; but in a more or less actively fertile condition, according to the original composition of the soil itself—its state of mechanical and chemical degradation—and the home-manuring and cropping to which it has been subject. What then are the circumstances, with these "*preliminary conditions*," under which produce in *agricultural quantity* is to be obtained? Baron Liebig says:—

"The ammonia of animal excrements exerts a favourable influence *only because it is accompanied by other substances necessary for its conversion into the constituents of the blood.* When these conditions are furnished with ammonia, the latter becomes assimilated. *But when the ammonia is absent from the manure, the plants extract their nitrogen from the ammonia of the air;* to which it is again restored by the decay and putrefaction of dead animal and vegetable remains."—p. 210, 211.

"But, at the same time, it is of great importance for agriculture, to know with certainty that the supply of ammonia is unnecessary for most of our cultivated plants, and that it may be even superfluous, *if only the soil contain a sufficient supply of the mineral food of plants, when the ammonia required for their development will be furnished by the atmosphere.*"—p. 212.

Referring to the mineral elements of the soil, Baron Liebig says:—

"If these elements are present in sufficient quantity, and in appropriate proportions, the soil contains the conditions which render *the plant* capable of absorbing carbonic acid and ammonia *from the air*, which is an *inexhaustible store-house for them*, and renders their elements capable of being assimilated by their organism. The agriculturist must, therefore, *confine himself* to giving to the field the composition necessary to the development of the plants which he intends to grow; it must be his principal task to supply and restore *all the elements required in the soil, and not only one*, as is so frequently done: the ingredients *of the air, carbonic acid, and ammonia*, the plants can, in most cases, procure *without man's interference;* he must take care to give to his

field that physical condition which renders possible and increases the assimilation of these ingredients *by the plant:* he must remove the impediments which diminish their effect."—*Address*—'*On the Principles of Artificial Manuring.*'—p. 16.

"The duration of the fertility of a field depends on the amount of the *mineral aliments* of plants contained in it, and its productive power for a given time is in a *direct proportion* to that part of its composition which possesses the capacity of being taken up by the plant."—*Address*, p. 10.

"Practice in agriculture has taught us that the amount of vegetable matters on a given surface increases with the supply of certain substances, WHICH WERE ORIGINAL CONSTITUENTS OF THE SAME SURFACE OF THE SOIL, and had been removed from it by means of plants. The excrements of men and of animals arise from plants; they are exactly the materials which, during the life of the animal, or after its death, obtain again the same form that they possessed as constituents of the soil.

"We know that the atmosphere does not contain these materials, and that it does not replace them; we know further that, by their removal from the soil, an inequality of production is occasioned, and, finally, even a want of fertility; but that, *by the restoration of these materials, the fertility may be sustained and even increased.*"—*4th Edition*, p. 164.

"*The fertilising power of manure can be determined by weight, as its effect is in a direct ratio to its amount in the mineral elements of the food of plants.*"—*Address*, p. 11.

The above quotations show what was the relative importance attached by Baron Liebig to the nitrogenous and the mineral constituents of manure respectively; and how far he has been misrepresented on this point, by the quotation from him of which he so much complains; namely, that "*the crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure.*"

We shall now proceed to point out what were the means insisted upon by Baron Liebig, as necessary to the *maintenance* and *increase* of production of *cultivated land;* by which a judgment may be formed, whether "it never occurred" to him "to assert that the land of Great Britain was deficient in the substances which are found together in the ashes of the crops raised on it." Baron Liebig says:—

"Is it conceivable, that a rich fertile land, with a flourishing trade, which has for centuries exported the products of its soil in the form of cattle and of corn, can retain its fertility, if the same trade do not restore to its land, in the form of manure, the constituents abstracted from it, and which cannot be replaced by the atmosphere? In such a case, would not the same fate await this land as that which befel Virginia, upon the soil of which wheat and tobacco can no longer be cultivated?"—*4th Edition*, pp. 164, 165.

Speaking of phosphate of lime and the alkaline phosphates, he says:—

"An enormous quantity of these substances indispensable to the nourishment of plants, is annually withdrawn from the soil and carried into great towns in the shape of flour, cattle, &c. It is certain that this incessant removal of the phosphates must tend to exhaust the land and diminish its capability of producing grain. *The fields of Great Britain are in a state of progressive exhaustion from this cause, ...*"—*Letters*, p. 522.

"If it were possible to restore to the soil of England and Scotland the phosphates which during the last fifty years have been carried to the sea by the Thames and the Clyde, it would be equivalent to manuring with millions of hundredweights of bones, and the produce of the land would increase one-third, or perhaps double itself, in five to ten years."—*Ib.* p. 523.

"If a rich and cheap source of phosphate of lime and the alkaline phosphates were open to England, there can be no question that the importation of foreign corn might be altogether dispensed with after a short time."—*Ib.* p. 524.

"It has been mentioned in the preceding part of the chapter, that animal excrements may be replaced in agriculture by other materials containing their constituents. Now, as the *principal action of the former* depends upon their amount of *mineral food*, so necessary for the growth of cultivated plants, it follows, that we might manure with the mineral food of wild plants, or, in other words, WITH THEIR ASHES; for, these plants are governed by the same laws, in their nutrition and growth, as cultivated plants themselves. Thus, *these ashes might be substituted for animal excrements;* and if a proper selection were made of them, we might again furnish our fields with all the constituents removed from them by crops of cultivated plants."—*4th Edition*, p. 182, 183.

Speaking of the exhaustion of alkalies by the growth of wheat and tobacco in Virginia, he says:—

"*Almost all the cultivated land in Europe is in this condition.*"—*4th Edition*, p. 118.

"It is also of importance to know, that the rule usually adopted in France and in Germany of estimating the value of a manure according to the amount of its nitrogen, is quite fallacious, and that its value does not stand in proportion to its nitrogen.

"By an exact estimation of the quantity of *ashes in cultivated plants*, growing on various kinds of soils, and by their analysis, we will learn those constituents of the plants which are variable, and those which remain constant. Thus also we will attain a knowledge of the quantities of all the constituents removed from the soil by different crops.

"The farmer will thus be enabled, like a systematic manufacturer, to have a book attached to each field, in which he will note the amount of the various ingredients removed from the land in the form of crops, and therefore how much he must restore to bring it to its original state of fertility. He will also be able to express in pounds weight, how much of one or of another ingredient of soils he must add to his own land, in order to increase its fertility for certain kinds of plants.

"*These investigations are a necessity of the times in which we live;* but in a few years, by the united diligence of chemists of all countries, we may expect to see the realisation of these views; and by the aid of intelligent farmers, we may confidently expect to see established, on an immovable foundation, a rational system of farming for all countries and for all soils."—p. 212, 213.

Speaking of the importation of phosphoric acid into Great Britain in the form of bones, in ten years, he says:—

"To have increased the fertility of the fields in the right proportion, 800,000 tons of potash ought to have been added to the 1,000,000 tons of bones in a suitable form."—*Address*, p. 13.

"The fabrication of a manure, equal in its composition and effects to the solid and fluid excrements of animals and men, seems to me one of the most essential demands of our time, more especially for a country like England,

which, from various circumstances, a rational agriculture, without a supply manure in some shape or other *from without*, seems nearly impossible."—, p. 24.

Now, on what principles, and by what constituents, does ron Liebig propose to provide England with a manure "*from thout*," equal in its composition and effects to genuine guano, d to the solid and fluid excrements of animals and men? He es on in the same page to say, "The following salts may be garded as the essential constituents of a powerful manure apicable to all descriptions of soil." He then enumerates under is head, all the constituents indicated by analysis in animal anures, including, not only the mineral constituents, but *mmonia, decaying vegetable matter*, &c. But, immediately afterards, speaking of the *mineral substances*, he says:—

"These are the substances which *together* give fertility to the soil; but though each of them may, under certain circumstances,—namely, where e soil is defective, or where it is not indifferent to the plant to take up one stead of the other, as, for instance, may be the case with soda instead of otass,—increase the fertility, no *one* of them can be regarded as manure, cording to the common meaning of the word, for the simple reason, that nly *all of them, in certain proportions*, will fulfil the purpose for which the ommon manure is applied. This purpose is the restoration, or an increase f the original fertility, and by manure we must replace *all the constituents f the plants which have been taken away in the harvest*, or which are *ntained in the plants which we are desirous to cultivate*."—*Ib.*, p. 26.

Having thus stated the principle upon which a manure *from thout*, and to replace guano and the solid and fluid excrements animals and men, should be compounded, he says:—

"What, then, are the constituents of the soil which we remove by the rvest, seeds, tuberculous roots, stalks, &c., of our plants of culture? It is rious that we must know these first, in order to *restore them in sufficient antities*. To this we answer, by giving *the analysis of the ashes of plants their seeds*."!!

After this overwhelming amount of evidence on the point—minating as it does to an almost exact reflection of what we e assumed in our Papers to be the *Mineral Theory* of Baron big as applied to agriculture—after all this evidence from own writings, we need scarcely ask:—

Is there in the sentence of our Paper, of which Baron Liebig much complains—is there, we ask, in that sentence, that of ich he should say:—

In it—"I find two erroneous statements, the continued difsion of which I can no longer tolerate"?

Or is he justified in asserting that he has never said—"That e produce of land is proportional to the supply or diminution the available mineral constituents"?

That—"I find in my work only one passage in which I speak the land of England in the sense understood by Mr. Lawes"?

That—"It is not difficult to refute the opinions of another, if we ascribe to him assertions which he has never made"?

And that—"It never occurred to me to assert that the land of Great Britain was deficient in the substances which are found together in the ashes of the crops raised on it," &c.?

Or, need we further ask—Where is the *Oxford version* * of the "*Mineral* Theory,"—namely, that "*it* throws upon the air, *or upon the ingredients of the manures which are organic in their origin*, the task of furnishing nitrogen to the plant"—where is there any trace of *this version* of the "*Mineral* Theory," in the overwhelming amount of Baron Liebig's own definitions of his peculiar doctrines which we have been quoting?

Secondly. We will now show how Baron Liebig's so-called "Mineral Theory" has been understood by other writers than ourselves, not only in England, but in Germany, France, and America.

Dr. Muspratt, formerly a pupil of Professor Liebig at Giessen, now Professor of Chemistry at Liverpool, and a son of the gentleman of that name who undertook the manufacture of Baron Liebig's manures in this country, commenting on a lecture by Mr. Karkeek, in which he had detailed the results of some experiments with Baron Liebig's manures, says:—

"It has long since been established that when the inorganic ingredients are *all* present, and in *sufficient quantity*, the *carbon and nitrogen the plants can assume from the air* without the interference of the farmer, if the land be in that physical condition which is requisite for the assimilation of the ammonia and carbonic acid present *in the atmosphere*."—*Mark Lane Express, March* 1, 1847.

Mr. Karkeek, in the course of his reply to Dr. Muspratt, thus indicates what he understands is the doctrine of which Dr. Muspratt was the representative:—

"Taking, then, these three experiments as they stand, and well knowing that the Trewithen meadow had been very highly manured for a long time, while the contrary was the case in the other two instances, I consider that I was not much out of the way in stating my opinion that the failure of Liebig's manure was the consequence of a want of sufficient quantity of azotised and (it should have been reported) carbonised matters in the soil; and whatever Dr. Muspratt may think to the contrary, notwithstanding I have such high authority to contend with, yet from the practice which I have had in observing the effects of various kinds of artificial manures during the past five years, I am quite satisfied that the inorganic elements are of very little value as a manure for plants without a corresponding supply of the organic. Indeed I am of opinion that plants have neither the power of assimilating the inorganic elements in the soil, or the organic substances from the atmosphere in such a degree as to enable the farmer to grow twenty tons of swedes to the acre, unless they are also supplied with a proper quantity of carbonaceous and azotised substances at the same time."—*Mark Lane Express, March* 22, 1847.

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* See *Saturday Review* of Nov. 10 and Dec. 1, 1855, *et seq.*

Again—The Council of the Royal Agricultural Society of England undertook a series of investigations as to the composition of the *ashes* of agricultural plants, with the object, in accordance with the doctrine of Baron Liebig, of ascertaining the manures required to restore to land its productive capability lost by the removal of previous crops, or to prepare it for the subsequent growth of this or that agricultural plant. In the course of this inquiry their able chemist actually provided recipes on the principle alluded to. But, as we well know, his own judgment and sagacity led him to doubt the sufficiency of the plan submitted to him to answer the ends supposed, long before his task had been concluded. Nor need we remind the reader, that investigations of a similar kind, and instigated by the same suggestions, have been made in many of the European laboratories with the same object; or further, that an immense number of manure-making schemes have arisen in England, Germany, France, and America, professedly founded on the principle alluded to.

In the 'North British Agriculturist' of November 7, 1855, the editor thus defines Baron Liebig's views:—

"Now, according to Liebig, ammonia is always afforded by the atmosphere in excess, while mineral matters, if not always, are at all events generally deficient in the soil; hence his inference is, that in order to increase the crop, it is only necessary to add the latter. He does not assert that ammonia is useless: on the contrary, he would have every farmer to add it to his soil, and that abundantly, if he happens to possess it; but if he proposed to lay out a certain sum of money in the purchase of manures, he would counsel him to expend it on *mineral matters*, and trust *to the atmosphere for the ammonia*, which he believes may be obtained from it in quantity *more than sufficient* for *the largest crop which it is possible to obtain.*"

Professor Johnston, in a lecture delivered at the York Meeting of the Royal Agricultural Society, in 1848, says:—

"A third opinion adopted by many, and extensively acted upon by some, that plants obtain all their organic matter *directly from the air*, and derive, and therefore require, *only mineral matter from the soil.**"—*Jour. Roy. Agr. Soc. Eng.*, vol. ix. part i., p. 223.

And, in a note to which attention is drawn by the star given at the end of his sentence, Professor Johnston gives the very sentence from Baron Liebig, which we are ourselves so much complained of for quoting, thus:—

"* 'The crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure.—*Liebig.*'"

In France—M. Boussingault, whose competency to judge of such matters is second to none in that country, and whose high character and authority as a philosopher and an agricultural chemist no one will doubt, thus indicates both his understanding and his opinion of Baron Liebig's doctrine—

"The view which assumes that the saline substances which manures contain, are their only really useful constituents would lead to advising farmers to burn their manure heaps in order to diminish the carriage, always such an inconvenience and so costly. I question whether this advice would ever be followed. Moreover, careful observation has shown that the organic substances in manure exert a very marked effect. Thirty square metres of infertile clay soil were manured with farm-yard manure, and yielded a very good crop of oats. By the side of this, on an equal surface, were spread the ashes (the salts therefore) of an equal quantity of the same manure; by so doing the produce was not sensibly increased."—*Economie Rurale*, vol. ii. p. 81-2 (Translated).

Another able French writer, M. Puvis, in his 'Traité des Amendements,' says (we give the passages translated)—

"Humus, in a soluble state, would be the peculiar food of plants, and would, moreover, furnish them with an incessant supply of carbonic acid, as the illustrious chemist of Giessen himself admits, though at the same time he *calls in question the necessity of animal manures*."—p. 423.

"The illustrious chemist of Giessen, having formerly admitted, in common alike with practical men and theorists, that ammonia is an essential and necessary constituent of manure, now regards it (ammonia) as one of the constituent principles of atmospheric air, and maintains that plants will derive it thence according to their requirements, as they do carbonic acid."—p. 623.

"*He then goes on to express a hope that the time may come when saline matters in small bulk will be substituted for animal manures.*"—p. 624.

"*In his new system he would almost exclude nitrogen, which however practical experience teaches us to look upon as one of the most active agents of production.*"—p. 624.

"Since the chemist of Giessen, Liebig, has proposed *to replace the manure heap by small quantities of saline substances*, and has himself set the example of the sale of these substances, propositions for new manures have rained upon us in all parts of Europe; in France, much more than elsewhere, manufacturing processes have risen up in all directions, to replace stable and other powerful manures by substances either in powder or in the liquid state, of a bulk fifty or one hundred times less than even the smallest quantities of manures which experience had sanctioned. Since 1842 we may reckon eighty-six patents of inventions for new manures, and all promise the highest productiveness."—p. 627.

"The chemist of Giessen has adopted the fundamental principle of the system of Duhamel, namely, that plants derive from the atmosphere all the volatile principles which enter into their composition; but considering that plants also contain fixed mineral principles which are not found in the atmosphere, and that successive crops would soon deprive the land of these substances necessary to vegetable organisation, he has thought it necessary to add to the system of Duhamel, as a necessary condition, that we must give to the soil the *mineral substances according to the composition of the crop that we wish to produce.* Convinced of the justice of his theory he thought to profit by it, and accordingly artificial manures modified to suit the nature of the soil, and the kind of crops, were sold under his name in Germany and England; the name of the distinguished chemist ensuring in these two countries a great number of trials, to which nothing in general was wanting but success."—p. 632.

"After the failures resulting from the use of the Liebig manures they were soon abandoned, and the analogous composts to which they had given rise, also quickly fell into discredit."—p. 635.

In Germany, —numerous writers have told us how they under-

stand Baron Liebig's doctrine; we quote from a few of these, some of whom have also given their opinion as to the truth of that doctrine.

Professor F. G. Schulze, of Jena, thus defines Baron Liebig's theory (we quote from p. 204 of the 'Patent Office Report' for 1848; Washington, 1849):—

"The stable manure which agriculturists furnish, essentially aids vegetable life, only by what it contains of alkalies, lime, silica, and other mineral elements, not by what it contains of carbon, hydrogen, oxygen, and nitrogen, for these substances plants can obtain from the air, as an inexhaustible source. As now in stable manures, the mineral elements bear the proportion of some two to seven per cent. of the whole mass, so the agriculturist, who yearly brings on his fields 100,000 cwt. of stable manure, carries out 93,000 to 98,000 cwt. in vain. It would be far more simple and less costly to give the plants only mineral manures, and to leave them to acquire their organic means of nutriment from the air."

"In the burning of plants, the organic, not the inorganic portions, are dissipated. Hence the agriculturist can burn his crops, namely, his straw, and yet continue his fields in the strength hitherto possessed, if he only carries on the ashes acquired by such burning. But if circumstances do not permit him to manure the plants with such ashes, yet can the same object be attained, if by the aid of chemistry he will examine into the ash constituents of his harvest, and carry the mineral substances corresponding to his analysis upon his field."

Dr. Weissenborn, of Weimar, in an article entitled 'Observations on Liebig's Patent Manure; with a Comparative View of the *Theories* of Thaer and Liebig,' thus expresses himself in regard to Baron Liebig's principles:—

"The *great rule* of the new system of manuring is the following:—Let the fields not be manured with stable-dung, nor with any sort of dung whatever that contains organic (vegetable or animal) substances, along with its inorganic (mineral) principles. This mineral manure the farmer has to procure, either by incinerating all the vegetable substances that he has reaped, and which he cannot profitably sell or consume on his farm, especially by burning the straw; or by applying to a chemist, with a view of having both the soil to be manured and the ashes of the plant to be cultivated duly analysed, and of getting prepared conformably to the result of such analyses an artificial manure (mineral manure, manure of ashes), containing the very mineral food that the plant wants, and that is not already contained in the ground."

"The *advantages* of the new system of manuring are represented to be the following:—

"1. The farmer saves almost the whole of the expenditure for transporting manure to the fields, as the weight of the mineral manure he wants is only 6 per cent. of that of the stable-dung hitherto used.

"2. On fields manured after the new system, the vegetation cannot materially suffer from want of rain.

"3. The straw may be sold; and most of the live stock, that scarcely ever yields a net revenue, may be dispensed with.

"4. The rotation of crops is rendered unnecessary, and any sort of crop may be raised on the same field without intermission.

"This *theory* of Professor Liebig is refuted by the following principle facts:"—&c., &c.—*Farmer's Magazine*, vol. xv. 1847, p. 369.

Professor Hugo von Mohl, in his 'Principles of the Anatomy and Physiology of the Vegetable Cell,' says:—

"Instead of reforming agriculture by his manures, Liebig has caused them to demonstrate the incorrectness of his *theory of the nutrition of vegetables.*"—*English Translation*, p. 80.

Baron Liebig, in his 'Principles,' recently published (p. 121–123), professes to wonder where Professor Wolff "has found what he calls the *pure Mineral Theory?*" Dr. Wolff answers him as follows:—

"As Baron Liebig does not seem to understand how I became acquainted with the so-called '*pure Mineral Theory*,' founded and even yet defended by him, I will enlighten him. By the Liebig Mineral Theory every one understands the idea which was to be practically carried out in the patent manure, namely, that when a soil has become exhausted by one or more crops, the *mineral constituents* necessary for the food of plants shall be restored to it in sparingly soluble compounds, and in such proportions as a chemical analysis of the crop would indicate. By means of the patent manure the same plants might be grown uninterruptedly on the same land, and a succession of abundant crops obtained."—*Zeitschrift für Deutsche Landwirthe*, 4en Heft, p. 11[illegible] 12 (Translated).

In America—much discussion has taken place regarding Baron Liebig's views. But, to save space, we will only give one quotation in connexion with that country. In a letter to Professor Webster, Professor E. N. Horsford, whilst with Baron Liebig at Giessen, writes, under date May 1, 1846, as follows (we quote from the 'Genesee Farmer' of August, 1855):—

"You are aware that Boussingault has expressed the opinion, after a variety of experiments, that the value of manure is in near relation to its percentage of ammonia. Mulder has, you know, written much in support of the view that ulmic and humic acids, ulmates, humates, &c., in one form and another minister largely to vegetation. . . . . *Liebig differs from them all.* . . . . He takes the position, that the sources of carbon and nitrogen are carbonic acid and ammonia *in the air.* . . . .

"It is obvious (from analyses of soils and rain-water) that the ammonia spread on fields in the ordinary distribution of barn-yard products *is of a moment.* The quantity with usual falls of rain *greatly exceeds*, in the course of a season, any conceivable supply by human instrumentality. . . . .

"But if, in the manure-heap and the liquid accumulations of the barn-yard transported to the fields, the ammonia be not the chief ingredient, or *an important one*, to what are we to attribute the unquestioned value of stable products and night-soil? Professor Liebig has shown, that if plants be manured with the ashes of plants of the same species, as the grasses of our western country are when burned over in the fall, they are supplied with their natural food. . . . . Let us consider what these ashes are, and what manure is. Herbivorous animals derive their nourishment from the vegetable kingdom exclusively, their food being grass, grain, roots, &c. These, with their organic and inorganic matters, are eaten. A portion of them is assimilated, becoming bone, muscle, tendon, fat, &c. Another portion is voided in the form of excrementitious matter. In process of time the bones and tissue follow the same course. What to-day forms the eye, with its sulphur, and its phosphorus, and carbon, &c., will have accomplish-

ffice, and left the organism to mingle with the excrements, or escape as onic acid and water from the lungs. At length all the *inorganic matters* re-appear in the voided products. . . . . The animal organism has rmed the office of a mill. Grain was supplied. Instead of appearing our and bran, and the intermediate meal, it appears, after intervals of ter or less length, in soluble *inorganic salts* in the liquid excrements, in luble *inorganic salts* in the solid excrements, and in carbonic acid and r. Now, after burning a plant, what remains? It contained, when grow- carbon, nitrogen, hydrogen, and oxygen, as organic bodies, and water. ntained also, in variable proportions, common salt, potass, soda, magnesia, , iron, phosphorus, sulphur, and silica. The first four were expelled in combustion. The remaining ingredients, for the most part, remained un- ged. Had the plant gone into the body of an animal, and in the course s evolutions through the organism lost its carbon, hydrogen, nitrogen, and gen, the remaining ingredients would have been the same as before. In case the plant would have been burned in the organism; in the other, in cible. *The ashes and the excrements are substantially the same.* . . . . Night- and guano are the *ashes* of animal and vegetable organisms burned in al bodies. They are the *ashes of plants*—the essential food of plants. ce *their value as manures.*"

So much, then, for the consistency of the interpretations of er writers—English, French, German, and American—with interpretations we have ourselves given of the Mineral ory of Baron Liebig. And how, we would ask, are these erpretations consistent with those now claimed by Baron big and his friends, namely, that "*The Mineral Theory*" hrows upon the air, *or upon the ingredients of the manure which organic in their origin*, the task of furnishing nitrogen to the nts"?

Baron Liebig shall answer for himself, whether it is upon he *manure*" that he throws "the task of furnishing nitrogen the plant." This one quotation and we have done with these gthy illustrations of Baron Liebig's views. In a letter to the itor of the 'Revue Scientifique et Industrielle,' a translation a part of which is given in the 'Farmer's Magazine,' vol. xvi. 347), p. 511, from which we quote, Baron Liebig says:—

'It has been demonstrated that ammonia is a constituent part of the atmo- ere, and that as such it is directly accessible and absorbable by all plants. hen, the other conditions necessary to the growth of the plants be satisfied— he soil be suitable, *if it contains a sufficient quantity of alkalies, phos- ates, and sulphates, nothing will be wanting: the plants will derive their monia from the atmosphere as they do carbonic acid.* We know well that y are endowed with the faculty of assimilating these two aliments, *and I lly cannot see why we should search for their presence in the manures we* . . . . . The question of the necessity for *ammonia in our manures* olves itself into the question of the necessity for *animal manures*, and upon e solution depends the entire future prospects of agriculture; for as soon as e can dispense with bulky farm-yard manure, by the use of artificial prepara- ns, the productive power of our fields is placed in our own hands."!

Thirdly. Having shown what was the "*Mineral Theory*" ad-

vocated by Baron Liebig prior to his recently published work, and how we and others have understood that theory as so advocated, we now pass on to the third main division of our subject; namely, to a consideration of the criticisms of our experiments and opinions regarding the growth of *wheat* and *turnips*; and, in the course of this inquiry, we shall endeavour, by the aid of the experiments quoted by Baron Liebig, taken with others by their side, to relieve the points which they are calculated to elucidate, of the mystery and confusion in which Baron Liebig has sought to envelop them.

In regard to our experiments on the growth of *wheat*, Baron Liebig says we have drawn the conclusions:—

1. "*That the mineral constituents of wheat cannot by themselves increase the fertility of land.*"

2. "*That the produce, in grain and straw, is rather proportional to the supply of ammonia.*"

We do not object to the definitions here given of our conclusions—*subject of course to the amplifications and qualifications which our own papers indicate.* But, notwithstanding in a public discussion on this subject, we utterly repudiated the definition of some of our conclusions assumed by Baron Liebig in summing up, and giving his verdict on our opinions at the end of his Treatise, he did not scruple to repeat those palpably incorrect interpretations of our meaning.

Let us now see, how it is that Baron Liebig seeks to show, that our own experiments contradict the above conclusions, Nos. 1 and 2.

Before we can do this, however, we must first clear the ground of a most ingenious objection, by which, as he cannot *deny* our facts, he would seek to throw them aside, as utterly unfit to be the foundation for any general conclusions regarding any other land than our own, or regarding agricultural practices generally.

Baron Liebig says,—

"Mr. Lawes has shown, in the most convincing manner, that in his land the mineral constituents of wheat were present in the greatest abundance and in an available form; and no one but Mr. Lawes himself can be surprised that, under such circumstances, by manuring with ammoniacal salts only, without any addition of mineral matter, he obtained during six years a higher produce than from the same land unmanured; for *theory plainly predicts such a result.*"—*Principles*, pp 78, 79.

"Mr. Lawes, then, as appears from these passages, chose for his experiments a portion of land which, on account of its being so rich in available mineral constituents, and of its other qualities, was utterly unsuited to his purpose, and which ought to have been unhesitatingly rejected, if the object was to test the value of the mineral food of plants. And since the mineral manure, in these circumstances, could not possibly have the effect expected by Mr. Lawes, his conclusions are destitute of all foundation in logic or in facts."—p. 59, 60.

Certainly, this is a very clever way of dismissing the whole of

xperimental evidence: and, in a similar manner, experi-
s on ten thousand different soils might be dismissed as ex-
nal, and therefore inapplicable to any other case than the
ular one in which the result was obtained. In other words,
lution of general agricultural questions is not within the
of field investigation!

t we propose to show, that *these assertions* are "desti-
of all foundation in logic or in facts," and that the land in
ion was perfectly adapted to the object in view in the expe-
its; which was, not simply to test the value of the *mineral*
of plants, but to ascertain what was the nature of the
re required—mineral or otherwise—to restore the produc-
apability for the increased growth of corn, which had been
sted by an unusually severe course of cropping on an
ry soil, and which, in the *ordinary* course of management,
l have had its productiveness again increased, by the use
e *ordinary* means of farm-yard manure, fallow, or green
ing.

e must repeat, then, that which we have reiterated so often
we are almost ashamed of again troubling our readers with
tatement, namely, that whatever might be the quality of the
elected (and it was certainly anything but one of the richest
of Great Britain, as described by Baron Liebig), it *was*
tate of *practical* or *agricultural* exhaustion, when first sub-
d to experiment. That is to say, it had grown a course
nips, barley, peas, wheat, and oats, since the application of
re; and it was by this treatment brought into such a con-
of comparative or practical unproductiveness, that no
r paying rent for it, and no landlord letting it, would allow
ain to grow corn without manure in some form. It was,
ver, as we have already said, in such a state of *practical* or
ltural infertility, that the use of the *ordinary* means of
re, fallow, or green cropping, would very greatly increase its
ce. And, whatever may be the opinion or the dictum of
y theoretical persons, however high their authority in their
lepartment of knowledge, we do not hesitate to maintain
the intelligent practical man, that a soil which had been
itted to the exhausting treatment above described, and
ht into the condition here stated, *was* in a fit and proper
for experimenting on with manures, in order to ascertain
ture of the corn-exhaustion it had suffered by a course of
ltural cropping.

, in order to *prove*, that the soil *was* in a state of agricultural
stion, and that it *was* in a condition to show the effects both
neral and organic manures, we have arranged in the fol-
g Table (1.) a condensed summary of nearly the whole of

the results obtained in the field in question, during a period of eleven years of the successive growth of wheat.

TABLE I.

Summary.—Results of Experiments on the Growth of Wheat.

Average Total Produce, and Total Increase (Corn and Straw), lbs. per Acre.

Series	General Description of Manures.	Number of Years.	Number of Cases.	Total Produce (Corn and Straw).	Total Increase (Corn and Straw).
				lbs.	lbs.
1	Unmanured	11	27	2864	..
2	Mineral Manure, only	8	40	3018	154
3	Farm-yard Manure	11	11	5036	2172
4	Ammonia-salts, only (Standard Amount)	9	36	4857	1993
5	Nitrate of Soda (= do. do.)	3	4	4907	2043
6	Ammonia-salts (= do. do.) with Minerals	9	117	5531	2667
7	Ammonia-salts and Rape-Cake (= do. do.) do. do.	6	12	5540	2676
8	Ammonia-salts (less than Standard) do. do.	6	17	4536	1671
9	Ammonia-salts (more do. do.) do. do.	8	31	6445	3581
10	Ammonia-salts and Rape-Cake (do. do. do.) do. do.	5	22	6016	3152

The plan of this Table (I.) is as follows. We have taken the average total produce per acre (corn and straw) of all the plots in each separate year which were unmanured, and then the average of these for the eleven years of the experiment: the number of cases in all, as seen by the Table, amounting to 27. In like manner the average is taken of all the cases in each year in which mineral manures alone were employed, and then the average of these results of the individual years, by dividing their sum by the number of years; and so on, with the cases where farm-yard manure, ammoniacal salts, or any of the other characteristic constituents or combinations, as indicated in the Table, were employed. The last column in the Table—that of total increase—represents the average annual total *increase* in lbs. (that is, corn and straw together), obtained from the manured over that of the unmanured plots.

We are not, it is true, favoured with any numerical statement whatever, either summary or in detail, of the experiments on the "Liebig's Height"; but we should not ourselves have thought of asking confidence in such a mere condensed summary as we now give, were it not that many of the results which go to form it, are already before the readers of this Journal, and the remainder we trust will be so in the course of time. This being so, we do not doubt that this summary will be accepted as both much more convenient, and better adapted for the discussion of the more prominent and characteristic facts, than a series of elaborate

tables of detail. Leaving, then, entirely out of the question, on this occasion, all detail or discussion as to the amount and specific description of the different manures, and also as to the varying proportions of corn and straw respectively, which make up the sum of the total produce, according to season, the manures employed, &c., let us see what are the broad and main features brought out by this immense mass of experimental evidence.

The average annual total produce (corn and straw) per acre *unmanured*, including the results of eleven years, and extending in all to 27 cases, is 2864 lbs. The average annual increase over this amount, obtained by various *purely mineral manures*, in 40 cases, distributed over eight different years, is only 154 lbs. The increase by *farm-yard manure* on the other hand, taking the average of eleven years, is 2172 lbs. It is clear, therefore, that there are here 2000 lbs. of increased produce, beyond that which the mineral manures were adequate to yield. Again, it is seen (in Series 4), that the average of 36 cases of *purely ammoniacal manure*, gave an average increase over the unmanured plots of 1993 lbs.; whilst *nitrate of soda*, another manure whose efficacy is due to the nitrogen it supplies, and which was applied in quantity as nearly as possible equal in nitrogen to that of the ammonia-salts, has given a mean average increase of 2043 lbs.

In the next series (6), we have 117 cases, distributed over nine years, in which ammonia-salts were employed, in quantity equal in their contents of nitrogen to the ammonia-salts of Series 4, and the nitrate of soda of Series 5; but we have here (in Series 6), the addition to the nitrogenous manure of various purely mineral manures; and the increase then rises to 2667 lbs. instead of only about 2000 lbs. with nitrogenous manure alone; so that, with this combined mineral and nitrogenous manure, the produce considerably exceeds that by farm-yard manure. Whilst, then, an excessive supply of nitrogenous manure alone has produced an average increase of about 2000 lbs., the further addition of minerals has, when there was at the same time a large amount of *nitrogen artificially provided within the soil*, given a further average increase of 674 lbs.; though, when these minerals were added *without* an excess of nitrogen in the soil, the average increase they yielded was only 154 lbs.

It is seen then, that mineral manures alone, increased the produce of this agriculturally exhausted field in no practical degree; that pure nitrogenous manures increased it nearly as much as the ordinary manure of the farm; and that nitrogen together with minerals gave a produce nearly double that of the unmanured land, and considerably exceeded that by farm-yard manure. "*That the mineral constituents of wheat cannot by themselves increase the fertility of land*"—and "*that the produce in grain and straw is*

rather proportional to the supply of ammonia"—would be conclusions from these simple facts, far more logical than many which we are expected to receive without any facts at all.

To proceed. May it not be said that the effect of the farm-yard manure upon the increased growth of wheat, was due in some way or other to its *carbonaceous* substance, rather than chiefly to its nitrogen, and to a small extent to its minerals in connexion with that nitrogen? This supposition is negatived by a comparison of the results of Series 7 with those already discussed, which throws some light upon the relative effects of the nitrogenous, the carbonaceous, and the mineral constituents of manure, upon the increased growth of wheat, on a corn-exhausted soil. Series 7 gives the average of 12 cases, distributed over six years, in which rape-cake, either with or without ammonia-salts, was employed in such quantity as to provide nitrogen exactly equal to the ammonia-salts of Series 6; and as in the latter, so also in Series 7, minerals were always added. We have here the striking result, of an average difference of produce of only 9 lbs. between Series 6 and Series 7, there being in the two cases an identity in amount of nitrogenous supply; and this, notwithstanding that the rape-cake employed in Series 7 would itself supply a considerable amount of additional minerals, and also a large quantity of carbonaceous substance, neither of which have given an appreciable increase beyond that of the equivalent nitrogen and minerals of Series 6.

In Series 8 we have, together with the minerals, *less* ammonia-salts than in Series 6; and with this *less* amount of ammonia or nitrogen, we have only 1671 lbs. of increased produce, instead of 2667 lbs. as in Series 6. In Series 9, on the other hand, we have with the minerals, *more* ammonia than in Series 6, and with this, a considerably increased amount of produce also; that is to say, when with the minerals we have applied a *larger* amount of ammonia in the manure than the "standard," we have an average annual increase of total produce per acre of 3581 lbs.; with only the "standard" amount of ammonia, an increase of 2667 lbs.; and with *less* ammonia than "standard," an increase of only 1671 lbs. And, finally, in Series 10, with minerals, rape-cake, and ammonia, containing together *more* nitrogen than in Series 6 and 7, we have, taking an average of 22 cases, and extending over a period of five years, an average increase of 3152 lbs.; instead of 2667 lbs. and 2676 lbs. in Series 6 and 7 respectively.

Surely in the results of this comprehensive summary of experimental evidence, we have good grounds for concluding, that this practically corn-exhausted field *was* in a condition to test the nature of that exhaustion, and of the constituents requisite to restore it to that condition of practical corn productiveness,

ıe ordinary means of farm-yard manure, fallow, or green
g would attain; and, if it be really so, there surely has
me light thrown upon the important question of the
of the efficacy of these well-recognised practices, so far
rowth of grain is concerned.

object of this inquiry really was, then, to determine by
nstituents of manure the produce could be raised from the
amount of its agriculturally exhausted state—no matter
r this was 17 bushels or 0—up to the point of which it
able by the ordinary means of intelligent and successful
g. This is the practical question, the question for *agri-*

And we repeat, that, inasmuch as by the means that
mployed we obtained an increase per acre of 10 to 15
s or more, with its equivalent of straw, over the produce
unmanured land, *whatever this last might be*—we say that,
was the case, our soil was in a fit and proper state to
ıte the important agricultural question as to what was the
of the exhaustion suffered by a course of agricultural
ng, and as to what constituents it was necessary to provide
the produce of grain could again be raised, from that of
ctically exhausted, to that of the *practically fertile* condi-
the land.

Baron Liebig has said that, because we obtained an average
e of 1125 lbs. of grain and 1756 lbs. of straw, during
consecutive years, that this was a sufficient proof—

> he soil was naturally so rich in available mineral constituents, of the
> quired by plants, that manuring with 4 cwt. of mineral manure per
> quantity which, spread over the ground and mixed with the soil
> epth of 12 inches, gives 1 grain to 20 cubic inches of soil, could most
> y produce no effect, or, at the utmost, a very trifling one. For, in
> year, the soil contained seven times, or about 85 per cent. more of
> bstances than was required for one crop."—*Principles*, p. 58.

r, if it really were so, that our "soil was naturally so rich in
ble mineral constituents of the kinds required by plants,"
ron Liebig admits, is it not the strongest condemnation
could possibly be conceived of the doctrine presented in so
forms to the farmer, namely, that "if only the soil contain
cient supply of the mineral food of plants," *then* "the
nia required for their development will be furnished by
mosphere"? Is it not, we ask, the strongest possible
nnation of such a view that, with the soil in this supposed
lly rich condition, the produce should still be *less*, by
bushels of corn, and their equivalent of straw, than that
ed on the simple addition of *available nitrogen to the soil?*
when Baron Liebig *now* informs us that—

> e but Mr. Lawes himself can be surprised that, under such circum-
> , by manuring with ammoniacal salts only, without any addition of

mineral matter, he obtained during six years a higher produce than from the same land unmanured; *for theory plainly predicts such a result*"—*Principles*, p. 78—

we ask, is not this again the condemnation by Baron Liebig himself of his own *previously* insisted-upon doctrines, as already shown in quotations from his works, and in other words in his letter to the editor of the '*Revue Scientifique et Industrielle*,' namely, that—

"if the soil be suitable, *if it contains a sufficient quantity of alkalies, phosphates, and sulphates, nothing will be wanting; the plants will derive their ammonia from the atmosphere*, as they do carbonic acid"? (!)

Again—with regard to the assertion, that the amount of mineral manure supplied in our experiments was so small in proportion to the whole bulk of soil, that it "could most certainly produce no effect, or, at the utmost, a very trifling one," we may answer—

1st, That mineral manures, applied to a similar description of soil, and in no greater proportion to its total bulk, have most marked effects upon the growth of *turnips* and our *leguminous crops*.

2ndly, That the same mineral manures, applied in the same proportion to the bulk of soil, have a distinct effect, even upon the *cereals*, *when there is an abundance of available nitrogen provided within the soil itself*.

3rdly, That salts of ammonia, and other compounds of nitrogen, applied in even less proportion to the bulk of soil, increase the produce of wheat in the particular soil in question, from that of agricultural exhaustion to that of high agricultural productiveness.

Let us now see by what kind of reasoning Baron Liebig believes that he can "convey to the reader the full conviction" that our own experiments not only contradict the conclusions "that the mineral constituents of wheat cannot *by themselves* increase the fertility of land," and "that the produce in grain and straw is rather proportional to the supply of ammonia," but that they are also the "strictest and most satisfactory proofs" of *his own* opinions.

Those of our results which he particularly brings under criticism with this view, are—

1st, Those of the continuously unmanured plot; and,

2ndly, Those of a plot (10*a*) which, after having had mineral manures in the first year, without yielding any practical increase of produce, had then ammonia salts only, for a series of years; by means of which, a large number of heavy crops have been obtained.

In Diagram I. (annexed) we have the results of these two plots, and those also of plot 10*b* by their side, from the commencement

To face page 31

Plots	1844	1845	1846		AVERAGE 1845-55
3	2043	4153	2720		2856
10a	2120	6246	4094		4534
10b			2671		4642
10a	77	2093	1374		1678
10b			49		1786

Explanation of Diag

	1855
Unmanu	2860
Mineral	3059
Ammoni	6265
Ammoni	
Mine	199
	3405

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of the experiment up to the present time—that is to say, from 1844 to 1855 inclusive. And, as before, we give in this place as little detail as possible, in order that the main and more general facts may stand out the more prominently.

The plan of the diagram is as follows :—

In the top line of figures are stated the years during which the experiments were conducted. In the second line of figures the total produce (corn and straw) per acre per annum of Plot 3; the continuously unmanured plot.

In the third line of figures, we have the produce of Plot 10*a*; which was manured in the first year with a mineral mixture, containing superphosphate of lime and silicate of potass, and in every succeeding year, with a somewhat excessive amount of ammonia salts only.

In the fourth line of figures is given the total produce of Plot 10*b*; which in the first year had the same minerals as Plot 10*a*, and afterwards, sometimes the same amount of ammonia salts as the latter, sometimes no manure at all, sometimes a complete mineral manure in addition to the ammonia salts, and sometimes the mineral manure alone.

And, in the two lower lines of the diagram, we have the *increase* of total produce over that of the unmanured plot, on the Plots 10*a* and 10*b* respectively.

And in order that the comparison, both as to the general character of the manuring, and the amount of produce, on the several plots, may be brought to one convenient view, the statement of the manuring is not repeated; but only indicated by squares of *colour*, which may be supposed to represent the different plots, thus :—

Unmanured—*uncoloured.*
Mineral manure—*blue.*
Ammonia salts—*yellow.*
Minerals and ammonia salts together—*green.*

Before entering upon a comparison of the results of the several plots, we must pass under review Baron Liebig's remarks on the produce of the *unmanured* plot; by which he not only seeks to show, that our soil was naturally so rich in available mineral constituents, as to be utterly unfit for experiment—an objection of which we have already disposed—but he also seeks to draw the conclusion from the variable amount of produce of the unmanured plot in different years, that this was due to the variable amount of mineral constituents dissolved in the soil in the same time; and hence, he seeks to claim the greater accumulation by the plant, in one year than in another, of carbon and nitrogen from atmospheric sources, simply as the result of an increased supply to the plant of *soluble or available minerals.*

Thus, comparing the produce of 1844 with that of 1845, the latter being twice as great as the former, he says:—

"If in the year 1844 a certain amount of rain fell on the land, and thus a certain amount of mineral constituents was rendered available for the plant; and if, in 1845, there fell, at the favourable season, one half more rain, this obviously dissolved one-half more of mineral constituents. Had these not been dissolved they could not have entered the plant and been there employed—that is to say, without their aid the crop of 1845 could not have increased by one-half.

"That to which, in these remarks, I wish particularly to direct the attention of farmers, is the fact that, in this striking case, the produce of the land in grain and straw, and therefore in nitrogenised matters, was much increased without the smallest addition of nitrogenous manure, for the land received no manure whatever; and solely from the increase in the amount of the mineral constituents, present in the soil, *dissolved in the same time.*"—*Principles*, pp. 69, 70.

Here Baron Liebig maintains that the larger amount of minerals dissolved by the increased fall of rain enabled the plant to appropriate the additional supply of nitrogen from atmospheric sources. We hold, on the contrary, that, owing to climatic variations, the *atmospheric supply*, either through the medium of the soil, or directly to the plants themselves, or both, was greater; therefore *the plants* were enabled to take up a larger amount of minerals from the soil. And that this was so, is, we think, susceptible of proof far more logical than the contrary supposition. Thus our experiments show—

1st. That the varying produce of the unmanured plot by no means bore any constant and direct relation to the varying amount of rain-fall of the different seasons; that is to say, to the amount of *mineral solvent*; but that, on the contrary, it depended much more on the coincidence with a certain amount of rain-fall, those conditions of atmosphere as to temperature and moisture which Baron Liebig himself admits must influence the amount of fluid passing through the plant, and which are also known imply a greater power in growing plants to assimilate atmospheric food—even though it cannot be supposed that they effect a *greater solubility of the minerals*. Whilst, without this greater available supply of atmospheric nutriment, either to the roots or to the leaves, the necessary and abundant mineral constituents in the soil would have been utterly unavailing.

2ndly. That a *direct supply of soluble mineral constituents* yielded scarcely any increase over the unmanured plot; while the supply of available nitrogen—*even with one and the same set of conditions as to mineral supply, rain-fall, and temperature*—nearly doubled the amount of produce. That is to say, increased supply of the normally atmospheric food of plants had a far greater effect in enabling the plants to take

from the soil and assimilate an increased amount of their necessary mineral constituents, than either the *direct supply of the soluble minerals*, or an *increased amount of rain or mineral solvent*.

The varying produce of the unmanured plot was therefore, *not* in proportion to the amount of soluble or available *soil-proper constituents*—that is, *minerals*—which, even when existing in excess, were utterly powerless, unless, either by climatic variations or by direct nitrogenous manures, additional supplies of the normally atmospheric food of plants were at the same time provided. True, no one will doubt the assertion, that "had these constituents not been present in the soil, an increased supply of carbonic acid and ammonia from the air could not have had any effect on the crop." Such an assertion, thanks to Baron Liebig, is at the present day a simple *truism*. And, we must here again remind the unwary reader, that the question between Baron Liebig and ourselves, has never been, whether or not plants could grow without a due supply of mineral constituents, but, as we have amply shown by the copious quotations given in the earlier part of this paper, Baron Liebig's doctrine has been—and indeed many passages in his new work would indicate that it still is—that "if only the soil contain a sufficient supply of the mineral food of plants," *then* "the ammonia required for their development will be furnished by the atmosphere"; or, as he now has it, when speaking of the varying produce of our unmanured plot, "a larger quantity of these mineral substances became active in the same time, and the surface of the land was thus enabled, *by the plants growing on it*, to absorb from the air one-half more carbonic acid and ammonia than in the preceding year." We, on the other hand, maintain, not that the mineral constituents can be dispensed with, but that in the ordinary course of agriculture with rotation, they exist relatively to other constituents in abundance, and that, notwithstanding this abundance, the main saleable produce of the farm, the *cereal grains*, are utterly incompetent to yield a full agricultural crop, unless there be artificially provided, *within the soil itself*, a liberal supply of available nitrogen, normally the atmospheric food of plants. The question, then, is, not whether mineral constituents are essential to the growth of plants, nor whether the supply of them in manure will yield an increase of grain *provided there be an excess of available nitrogen within the soil*—for both of these postulates we need not say we fully assent to—but it is and has been, whether or not a liberal supply of the soluble mineral constituents of the cereals, to a soil suffering the exhaustion of an ordinary course of rotation, will enable the crop to assimilate in any practical and agriculturally adequate degree, a larger amount of nitrogen from atmospheric sources?

To this we answer in the negative. And, let us see, how Baron Liebig seeks to show that our experiments contradict the equivalent assertions—"that the mineral constituents of wheat cannot *by themselves* increase the fertility of land," and "that the produce in grain and straw is rather proportional to the supply of ammonia."

We have before explained (see Diagram I.), that plot 10 of our experimental wheat-field was manured in 1844 with a mixture of silicate of potass and superphosphate of lime, and in every subsequent year one portion of it (10*a*) received a very liberal amount of ammonia salts only: the result being a very considerable increase of produce compared with the unmanured plot. This increase, according to Baron Liebig, is due to the—

"constituents of the soil, plus 560 lbs. of superphosphate of lime, plus 220 lbs. of soluble silicate of potass, plus 1960 lbs. of ammoniacal salts;"

And he goes on to say—

"it follows that the increase of produce was by no means the effect of the ammonia alone, as Mr. Lawes will have it, but that the active mineral constituents of the soil just mentioned have had their full share in producing this effect.

"What, then, are the circumstances in which theory leads us to anticipate such an increase of produce?

"The answer will be found in my work, p. 134."

We give the sentence as it really does occur at page 134 of the fourth edition of Baron Liebig's work, the portions between brackets, thus [ ], being omitted by Baron Liebig in his quotation (*Principles*, p. 109):—

"The cereals require the *alkalies and silicates* liberated by the lime, and rendered fit for assimilation by plants. If there be present decaying matter yielding to the plants carbonic acid, their development may be favoured by this means; but this is not necessary. For if we furnish to the soil ammonia, and to the cereals the phosphates essential to their growth [*in the event of their being deficient*], we furnish all the conditions necessary for a rich crop [*as the atmosphere forms an inexhaustible magazine of carbonic acid*]."

Now, the object of this sentence in Baron Liebig's work was simply to explain that the beneficial action of burnt lime upon soils depended upon its liberating in the soil, the "*alkalies and silicates*" which the cereals require, and that, as the amount of humus must thereby be lessened, it was obvious that, *in the event of other constituents not being deficient*, the plants were enabled to rely upon *the atmosphere* as *an inexhaustible magazine of carbonic acid*. Whether or not Baron Liebig's "Theory," as amply developed in entire chapters of the same work, as well as in other writings, is properly represented by this individual and mutilated sentence, the reader will judge for himself, from the evidence we have adduced as to what that theory really was.

But can the increase of produce of plot 10*a* over the unmanured plot be attributed to the efficacy of the mineral constituents supplied in the first year, in the sense in which Baron Liebig attributes efficacy to soluble mineral manures; namely, as increasing the assimilation of nitrogen from *atmospheric* sources?

Diagram I. shows that the minerals alone (superphosphate of lime and silicate of potass), which were employed in 1844, gave only 77 lbs. more produce than the unmanured plot.

In 1845, a liberal supply of ammonia salts alone, to this plot 10, on which soluble minerals alone had given scarcely any increase in the previous year, increased the produce over that of the unmanured plot by more than 2000 lbs.

In the third year (1846), this plot 10 was divided into two equal portions. One-half (10*a*) again received ammonia salts alone, and the other (10*b*) no manure at all.

Now surely, if the soluble minerals supplied in the first year, are to have so much of the credit of the increase of crop during the seven years, and if, with "a sufficient supply of the mineral food of plants," . . . "the ammonia required for their development will be furnished by the atmosphere," surely, upon these suppositions, we ought to get some increase of produce over the continuously unmanured plot, on plot 10*b*, in this third year (1846); when, having had, but two years previously, this supposed very efficient supply of minerals, it is now left unmanured. The fact is, however, that in 1846 the *continuously* unmanured plot gave 2720 lbs. of total produce, and plot 10*b* only 2671 lbs. !—though 10*a*, where ammonia salts were again applied, gave 4094 lbs.! The result is, then, that plot 10*b*, with minerals in 1844, ammonia in 1845, and no manure at all in 1846, gave even rather less produce than plot 3 (the continuously unmanured plot), which had had no supply of minerals at all. How, we would ask, are these facts consistent with attributing the increased produce during the seven years on plot 10*a* "*to the one only constant value which operated*" *in the experiments*—"that is, *to the total sum of the available or soluble nutritive mineral constituents present in the soil*"? The obvious truth is, that however liberal the supply of minerals in the soil, they were utterly incompetent to yield any agriculturally adequate increase of produce of wheat, unless accompanied by an artificial supply of available nitrogen within the soil; and this being so, we would ask—Was not the produce "*rather proportional to the supply of ammonia*"?

In 1847, plots 10*a* and 10*b* both received equal amounts of ammonia-salts alone, and gave nearly identical amounts of produce, and half as much again as the unmanured plot.

In 1848, the produce of the unmanured plot was 2664 lbs.; that of 10*a*, with ammonia salts only, for the fourth year,

3701 lbs.; but 10*b*, with minerals and ammonia, gave
Here, then—*after growing wheat successively year afte*
means of very large amounts of ammonia-salts, upon
riously exhausted by a heavy course of cropping—we find
effect from the admixture of minerals with a further d
ammonia. But is this action of minerals in rendering
an excessive supply of ammonia in the soil, after such a
mineral exhaustion as never happens in the ordinary
farming with rotation—is this the action still insisted
Baron Liebig, namely, that of enabling the surface of
"*by the plants growing on it*, to absorb from the air'
amount of carbonic acid and ammonia?

In 1849, both plots (10*a* and 10*b*) were again supp
equal quantities of ammonia-salts alone, and both gave
2000 lbs. increase over the unmanured plot; whilst 10*b*
liberal supply of minerals the year before, only gave
more than 10*a*.

In 1850, ammonia salts alone on 10*a* again gave
2000 lbs. of increase; but 10*b*, to which minerals we
—this time *without ammonia*—gave only 399 lbs. of
produce, this slight amount being chiefly due to a sma
of ammonia remaining in the soil from the high an
manuring of the previous years.

That the minerals employed in 10*b*, though yield
399 lbs. of increase, still practically exhausted the soil
mediately available supplied ammonia is obvious from t
of the next two years (1851-2). Thus, with a large a
supply of ammonia-salts only to both plots (10*a* and 10*b*
two years, we have almost identically the same amount o
on the former as on the latter; although 10*b* had
twice received a liberal supply of minerals, which
withheld from 10*a*, but had also given a less gross total
reckoning from the commencement of the experiment.

From this time—although the continued applicatio
monia-salts only on 10*a*, gave in the ninth year an i
919 lbs.; in the tenth, of 2312 lbs.; and in the ele
937 lbs. of corn and straw—the employment on 10*b* of
in addition to the excessive amount of ammonia, produ
further increase.

What, then, is the general result of these expe
Excluding the first year, in which the plots 10*a* and
received mineral manure without yielding any practica
of increase, it is as follows:—On the average of eleve
the continuous growth of wheat, the unmanured plot ga
annual produce (corn and straw) of 2856 lbs.; plot
eleven years of ammonia salts alone, gave 4534 lb

an *increase* over the unmanured plot of 1678 lbs.; and plot 10*b*, with nine years of ammonia salts and two years of minerals, gave an annual average of 4642 lbs. of total produce, and of 1786 lbs. of *increase*. That is to say, plot 10*b* has only given during these eleven years, an annual increase of 108 lbs. more total produce than plot 10*a*, although during this period it received considerably more than ten times as much of all the more important mineral constituents, except silica, as would be contained in the total increase in the eleven years, of 10*b* over 10*a*! In fact, all that this mineral supply has done, has been to render efficient *that amount of ammonia*, which was *added in excess* of the annually available supply of minerals from the soil itself.

But in Diagram II. (p. 31), we have even a more striking answer still, to the assertion that in our experiments the whole produce is proportional "*to the total sum of the available or soluble nutritive mineral constituents present in the soil.*" The produce of two plots (17 and 18) is here compared with that of the continuously unmanured plot. The results extend over a period of six years, namely, 1850 to 1855 inclusive. As before, the *unmanured* space is *uncoloured; mineral manures* are represented by *blue; ammonia-salts only* by *yellow;* and the *mixture of both minerals and ammonia* by *green.*

It should be mentioned, that the plots (17 and 18) had, previously to 1850, been manured somewhat similarly since the commencement of the experiment in 1844. They had generally received a liberal supply of minerals and of nitrogenous matter also; plot 17 having had upon the whole rather more nitrogen supplied to it than plot 18.

In 1850, both plots (17 and 18) received a large amount both of soluble minerals and of ammonia-salts, and they each gave nearly a ton and a half more produce than the unmanured plot; though plot 17, which had been rather the most highly manured throughout the previous years, gave rather more produce than plot 18.

In 1851, plot 17 received the same amount of minerals and ammonia as previously, and gave 2905 lbs. of increased produce. Plot 18 received no minerals, but the same amount of ammonia as plot 17, and the result is nearly as much increase, that is, 2864 lbs. instead of 2905 lbs.

In 1852, plot 17, which had minerals and ammonia the year before, has now only ammonia; and plot 18, which had ammonia only in the previous year, has now only minerals. The result is, that the ammonia plot (17) gives 5418 lbs. of produce, or 2691 lbs. of increase; whilst the mineral plot (18) gives only 2620 lbs. total produce=only 163 lbs. increase.

In 1853, the plot which had previously ammonia only, has now only minerals; and the one which had minerals only, has now only ammonia. And we have again with the ammonia 4773 lbs. of produce = 3001 lbs. increase; and with the minerals only 2533 lbs. of produce = 761 lbs. of increase.

In 1854, the manures are again transposed; and this being a very favourable season, we have, with the ammonia, 7923 lbs. of produce = 4427 lbs. of increase, or nearly 2 tons; and with the minerals only, 3915 lbs. of produce = 419 lbs. of increase, or *more than 4000 lbs. per acre less increase than with the ammoniacal salts.*

Lastly, in 1855, the manures being again transposed, so also is the relation of produce on the two plots—the ammonia plot giving 6265 lbs. of produce = 3405 lbs. of increase; and the mineral plot only 3059 lbs. of produce = 199 lbs. of increase.

Tracing the history of each plot separately, the *increase over the unmanured plot* is as follows:—Plot 17, with minerals and ammonia, in 1850, 3332 lbs.; with the same in 1851, 2905 lbs.; with ammonia only in 1852, 2691 lbs.; with minerals only in 1853, 761 lbs.; with ammonia only in 1854, 4427 lbs.; and with minerals only in 1855, 199 lbs. of increase. Plot 18 again, with minerals and ammonia in the first year, gives 3054 lbs.; with ammonia only in the second year, 2864 lbs.; with minerals only in the third year, 163 lbs.; with ammonia only in the fourth year, 3001 lbs.; with minerals only in the fifth year, 419 lbs.; and with ammonia only in the sixth year, 3405 lbs. of increase, in each case, over the unmanured plot.

We ask then, do these results either contradict the assertions, "that the mineral constituents of wheat cannot *by themselves* increase the fertility of land," and "that the produce, in grain and straw, is *rather proportional to the supply of ammonia*"?—or do they "*prove*" what we "intended to *disprove*," namely, that the whole produce is proportional "to the total sum of the *available or soluble nutritive mineral constituents present in the soil*"?

What the "*Mineral Theory*" of Baron Liebig, as developed in his previous writings, really was—how that theory was understood by others as well as ourselves—and how independent, according to it, our cultivated plants should be of available nitrogen supplied to the soil, if only they are liberally provided with their necessary mineral constituents—the reader is by this time fully aware. He has also seen, that in passages and arguments in Baron Liebig's recently published "*Principles*," this identical "Mineral Theory" is still maintained; and also, how strenuously he has endeavoured to show, that the increase of produce in our experiments was due, not to

» efficacy of the ammoniacal salts employed, but "to the total
n of the available or soluble nutritive mineral constituents
»sent in the soil." *But now for the other side of the question!*
Besides stating, as already pointed out—and in spite of his
gthened argument and summing up to the contrary—that the
rease we obtained by manuring with ammoniacal salts alone,
s only what theory plainly predicted, he says—

: When we remember that it is the object of scientific research to discover
cause of the efficacy of ammoniacal salts, we must not forget, in our in-
ries, *that the increase of produce, obtained by the use of these salts, is to be*
rded in itself as a firmly established fact, which can in no way be affected
the views we may entertain as to its cause."—*Principles*, p. 98.

The efficacy of ammoniacal salts in yielding an increase of
duce, not only in our own experiments, but as a "*firmly-*
blished fact," is now then fully admitted. And as it was
possible, in the face not only of our own particular experi-
nts, but of now generally recorded experience, to avoid this
nission in some form, how is it that Baron Liebig brings this
ult into consistency with the theory which supposes the
rease to be proportional to the soluble *minerals* present
the soil? We could blush for Baron Liebig as we quote his
rds:—

In these experiments, three portions of land were each manured, for
n years, with *mineral manure* (mineral constituents of the soil *and*
oniacal salts). . . . ."

d again, in the same page—

: follows from this, that *farm-yard or stable manure can be replaced in*
ntire effect by mineral manure; and not only replaced, for it can be, by
use of *mineral substances alone* (*sulphate of ammonia and sal-ammoniac*
mineral), surpassed in its fullest efficacy."—*Principles*, p. 90.

Thus then "ammoniacal-salts," "sulphate of ammonia, and
-ammoniac," are to be classed as *mineral manures!* This is in-
d begging the whole question! But a manœuvre so transparent
this, would not even require notice, were it only addressed to
scientific reader. As it is, however, it is necessary to remind
uninitiated or unwary, that throughout the discussions on
subject of agricultural chemisty during the last ten or a
en years, the term "*mineral manure*" has acquired an entirely
hnical significance, and that it has been employed to designate
e constituents which, when assimilated by the plant, would
ain as *ash* after its incineration; and it has been used, empha-
lly to distinguish such constituents of plants or manures, from
combustible or volatile portions—that is, from the nitrogenous
ammoniacal, the carbonaceous, &c. Indeed, we need not go
to establish, from the words of Baron Liebig himself, the

cognised distinction, in *agricultural* discussions, between the rms *mineral*, and *ammonia* or *ammoniacal*. Thus he says:—

"The *mineral* constituents act, as is shown by the produce of the unanured land, without any artificial supply of *ammonia*."

"The *ammonia* increases the produce only if the *mineral* constituents be present in the soil in due quantity and in an available form."

"*Ammonia* is without effect if the *mineral* constituents are wanting. Consequently, the action of *ammonia* is limited to the acceleration of the action of the *mineral* constituents in a given time."—*Principles*, pp. 86, 87.

". . . The other is the action of *sulphate of ammonia* as a solvent for certain important *mineral* constituents of the soil."—*Ib.* p. 99.

"*Ammonia*, when used as a manure alone, and when there is a want of *mineral* constituents in the soil, is like the spirits which the labourer takes, in order to increase his available labour, power, or imagination."—*Ib.* p. 106.

It is needless to multiply quotations. The *ruse* has not, however, been entirely without success. For in public discussion of the subject at the late Meeting of the British Association, before Baron Liebig himself, one of his advocates stated, that the difference between Baron Liebig and ourselves rested mainly on a misunderstanding—on a different use of nomenclature—for "*salts of ammonia are mineral manures*"! This method of begging the whole question was, however, we were glad to find, entirely disallowed by mutual friends of Baron Liebig and ourselves with whom we conversed on the subject; and we are glad to find, that writers of the agricultural press have also expressed their sense of this manœuvre. Thus, in an able article on this discussion in the "North British Agriculturist" (Nov. 7, 1855), the writer says—"Neither can we think him justified in claiming *sulphate of ammonia and sal-ammoniac* as *mineral* substances ('Principles,' p. 90), which is simply *begging the whole question at issue*."

But Baron Liebig has yet another way of claiming the necessarily admitted action of ammoniacal salts, as one of *mineral*. Thus he says:—

"Now, since sulphate of ammonia and sal-ammoniac, in the same way carbonic acid, increase the solvent power of water for these essential ingredients of the food of plants, the question at once arises, whether their good effects may not depend in great part on *this* property, and whether, in the experiments of Mr. Lawes, the whole effect of the ammoniacal salts do not consist of two actions, namely, that of ammonia, as food for plants, as a source of nitrogen, and that of its salts as replacing carbonic acid? The answer to this question may serve to reduce to its real value the assertion of Mr. Lawes (xii. p. 24), 'that it would be much nearer the truth to say that the crop has risen and fallen in proportion to the diminution or increase of the ammonia supplied to it in manure.'"—*Principles*, p. 91-2.

"But if, on the contrary, only a small part of the ammonia acted by its nutritive property, and by far the greater part by its solvent power for *phates* and *silicates*, its action is explained in a more satisfactory manner in this case the effect is proportional to the quantity of water which en the plants, and was given off by evaporation from their surface, the so

ower of this water for these substances having been increased by the ammoniacal salts. The effect of the *earthy phosphates* and of the *soluble silicates* epends on the quantity of them in the soil; their effect in a given time is roportional to the quantity which enters the plant in that time. This again s proportional to the degree of their solubility in rain-water, and to the amount f rain-water absorbed by the plant."

"Both properties—that of ammonia as a *nutritive agent*, or source of itrogen, and that of the ammoniacal salts as *solvents*—have certainly coperated to give the increased produce; for since the total produce, 28,431 lbs. f grain and straw, of the lot manured with ammoniacal salts, was to that of he unmanured land, 18,122 lbs. grain and straw, as three to two, and consequently the excess of the former was equal to half the amount of the latter, t is evident that this excess must have contained exactly as much silicate of potass and phosphates as existed in one-half the crop of the unmanured land. Now, since ammonia cannot replace these essential constituents of the wheat-plant, it follows, that, by the agency of the ammoniacal salts, this entire additional quantity of mineral constituents was rendered soluble and available for the plant. These salts have enabled the rain-water, in equal volume, to dissolve and carry into the plant, in the same time, one-half more of these substances than was yielded, without ammoniacal salts, by the unmanured land."—*Ib*, pp. 99–101.

We are here told, then—*in March*, 1855—that the efficacy of the salts of ammonia in our experiments is to be attributed in a great measure to their *solvent action* on the *phosphates* and *silicates* of the soil; the increase of produce being greatly due to the consequently increased supply of these minerals to the plant. The reader will imagine therefore our astonishment, when, in *September of the same year*, we heard Baron Liebig in the public discussion of our experiments, energetically maintain, that the presence in the soil of ammonia and its salts must *reduce the solubility of the silicates!* We have since found, that he had then already published two papers in Germany, in the course of which he sought to establish the latter view. We are not disposed to dispute the probable truth of this amended conclusion. For, in experiments instituted with the view of testing the probability of Baron Liebig's *previous* assumption, we had found that water containing *salts of ammonia*, when percolated through a given bulk of soil, *dissolved less silica* than pure water so percolated. At the same time, however, we must say, that we cannot admit the legitimacy of deductions from experiments made upon *pure silicates out of the soil*, as to what would happen under the complicated and little understood chemical conditions of *cultivated soils*.

At any rate, however, we must conclude, that Baron Liebig's explanation of the efficacy of ammonia-salts in our experiments, so far as it supposed an increased supply to the plant of *silica*—the characteristic mineral constituent of the crops to which ammonia as a manure is peculiarly adapted—is now abandoned!

But what of the *phosphates?* We will neither assert nor deny,

that these important mineral constituents may be rendered more soluble in the soil, in a given amount of water, provided this water contain ammonia salts. But, whether or not the increase in the produce of grain and straw in our experiments, was in any important degree due to this cause, is quite another question. Upon this point some opinion may be formed from the following considerations:—

How is it, we would ask—if, in the experiments where ammonia-salts alone were employed for a series of years, "only a small part of the ammonia acted by its nutritive property, and by far the greater part by its solvent power for phosphates"—how is it, we would ask, if this were the case, that the addition of a very much larger *direct supply of phosphates* than the increase of crop could require, indeed in an amount and in such a form of easy solubility as to yield extraordinary results with some other crops than the cereals, should, with the latter, when used without ammonia, give scarcely any increase whatever? In other words, are we to suppose a greater amount of phosphates to be rendered soluble from the stores of the soil itself, by the solvent action of the ammonia-salts employed, than by the *direct use*, in an *easily soluble form*, of many times more phosphates than the increase of crop could require? On this point we may state that the increase of produce on plot 10*a* contained an annual average of 6 to 7 lbs. of phosphoric acid; whilst ten times that amount was the general dose of that acid supplied to the soil in our experiments when mineral manures were employed—a large part of it existing, when added to the soil, in that form of easy solubility as superphosphate of lime, which is found so efficient for other crops than the cereals, the remainder existing as very finely powdered earthy phosphate.

Would it not be both more candid and more consistent, instead of thus wrestling to the last to maintain the shadow of an obviously half-abandoned theory, to attribute the increased assimilation of minerals on a given space of ground, which is necessarily incident to an increase of crop, rather to a multiplication of the feeders of the plants, and an increased vigour of growth under the influence of nitrogenous supply, which, by virtue of the larger amount of soil-solution which must be absorbed, enables them to take up with it more of those minerals which were obviously neither wanting nor insoluble; although they cannot be assimilated by the cereals beyond a limited amount (varying with atmospheric supplies), unless *nitrogen in an available form* be at the same time provided *within the soil itself?*

We proceed next to show how, the effects of available nitrogen supplied to the soil being necessarily admitted, the fact of its being thereby enabled to yield an increase of produce, is not to

be considered as an increase of *fertility;* and the farmer is therefore to be cautious how he adopts any such ruinous means of raising the produce of his land. Baron Liebig says:—

"In that work of mine I have fully explained that the idea of fertility in a soil, essentially comprises that of the *continuance and duration* of the crops. No one regards as fertile land such as, without manure, bears good crops for a year or two, and no more. In this point of view, the fertility of a soil is in direct proportion to the conditions of fertility present in it; that is, to the *mineral substances* which are necessary for the nutrition of plants."—*Principles*, p. 75–6.

"If we manure the same land with 3 cwt. of ammoniacal salts, we shall have, in one year, a crop one-half heavier than on the unmanured land; we shall obtain annually one-and-half crops, or, in eight years, the produce of twelve average crops. That is to say, the soil will have lost, in eight years, as much mineral matter as it would have lost in twelve years without ammoniacal salts; it will therefore be exhausted, or become unfruitful for wheat, four years sooner than if no ammoniacal salts had been used.

"I hold, therefore, that which in my work I have endeavoured so fully and minutely to explain, that, in reference to the exhaustion of the soil, *ammonia* or *ammoniacal salts, used alone*, are the kinds of manure which impoverish a soil, or in other words, consume the capital of the land, the most rapidly.

"In one case only does the fertility of the soil manured with ammonia, or its salts, maintain itself, namely, when these are accompanied by the mineral substances which are annually removed in the crops. These may be restored either by annually adding as much as is removed, or by adding after the fifth crop a five-fold quantity of them. If this be once omitted, the effect must become perceptible in a series of years.

"The rational agriculturist must not believe, that he can remove from a rich fertile soil, without any compensation whatever, a part of its constituents, and not, by so doing, sooner or later impair its fertility; for this fertility, or the produce in a given time, is the effect of the whole sum of the actions of all its constituents; not only of that portion of them, which has entered the plants, but also of the rest of the available supply, which is left in the soil. The entire supply, or sum, has produced this result, namely, that the roots found everywhere their necessary food; and if we remove a part of the whole supply of these constituents, then the roots will no longer find their proper food in that part of the soil where they are wanting.

"Let us only suppose that during the last few centuries our ancestors had acted on the principles here laid down, in their full extent and strictness; what a paradise of fertility would England be at this day!"—*Ib.*, p. 81–3.

We must here first notice the running insinuation in these passages, that we would recommend as a practice for adoption in agriculture generally, the continuous growth of corn by means of nitrogenous manures, without any other return to the land. It is only to those who have never read our Papers, that it is necessary to say, that a more incorrect impression of our views could not possibly be given than that which is herein implied; and which is more plainly, if not more courteously, expressed in the following sentence:—

"It is not easy to understand how Mr. Lawes could deduce from his results the conclusion '*that nitrogenised manures are peculiarly adapted for the cul-*

ture of wheat,' since such manures can only produce a favourable result [illegible] certain *preliminary conditions, which Mr. Lawes has entirely disregarde[illegible]* be fulfilled. There could hardly be made an assertion better calculated [illegible] o mislead the practical farmer."—*Ib.*, p. 79.

To meet these gratuitous statements from such a quarter, it [illegible]s necessary to repeat, then, that the whole of our recommendation[illegible]s to the farmer in this matter, have been repeatedly and elaborate[illegible]y defined, to apply to agriculture as generally practised in th[illegible]s country, that is to say, agriculture *as it is*—the "preliminary co[illegible]- ditions" which we have supposed being, a *cultivated soil*, and [illegible]a *rotation of crops*. And what, then, does a rotation of crops in th[illegible]s country involve? It involves the growth of root and other fallo[illegible]v crops; the growth of these involves the feeding of animals on th[illegible]e farm; the feeding of animals on the farm involves the productio[illegible]n of home manure; and the production of home manure involv[illegible]s the "*preliminary condition*," of a periodical return from the [illegible] sources *within the farm itself*, of a large proportion of the mine[illegible]al constituents which have been removed from the land in the crop[illegible]s. Into all this we have gone with considerable detail, again, a[illegible]d again;—as well on the assumption of there being, as of the[illegible]e not being, a certain amount of imported constituents to be furth[illegible]er taken into the calculation. With this explanation we will aga[illegible]n apply to Baron Liebig his own words:—"It is not difficu[illegible]lt to refute the opinions of another if we ascribe to him assertio[illegible]ns which he has never made."!

But now for the assertion that *fertility* is almost exclusive[illegible]ly referable to the *mineral* richness of the soil. True, there c[illegible]an be no fertility *without* a liberal provision of minerals; b[illegible]ut what, we would ask, is the use to the practical farmer of ma[illegible]in- taining his land in a condition of so-called "*fertility*," whic[illegible]h, *without the addition of something else*, will yield him no increase of produce whatever? What, we would ask, is the use to the farmer, of a merely *latent* or *reserved* capability of production, if this latent capability be not brought out into *activity* and *use*? And it is undoubtedly true, that in agriculture generally, with rotation, there is a considerable accumulation of this latent or re- served capability of production, which cannot be brought into activity and use for the increased growth of the main saleable pro- ducts of the farm—the cereal grains—without the accumulation, *within the soil itself*, of *available nitrogen*. Again, experience shows, that by the production of grain, the stores of *available nitrogen within the soil* are far sooner exhausted or brought down to an annual *minimum*, than those of the minerals. How much more strongly, then, to be consistent, should the argument be applied against the exhaustion of the land of its *available nitrogen!* And should not Baron Liebig, in obedience to his own principle of *non-*

caution, precisely reverse the advocacy reiterated in the following sentence?—

> I had myself, in the first edition of my work, attributed to *ammonia preponderating* value and importance; *and I thought I had sufficiently corrected this error in the subsequent editions.*"—*Principles*, p. 79.

Surely, if any of the constituents necessary to the production our crops, should have, in the eye of the *agricultural chemist*, *preponderating* value and importance," it should be those which the *most* easily, not those which are the *least* easily, exhausted the course of practice!—those by the want of which the limit to production of corn is in practice fixed—not those which, in same course of practice, are ready and waiting, but inactive, remant, and unremunerative, because unassociated with others hich we are told should nevertheless not have attributed to them, *preponderating* value and importance"!

But we have not yet done with the limitations to a free and qualified admission of the pre-eminent importance in agriture, of an accumulation of *nitrogen in an available form within soil itself*:—

> "The advantage of this artificial supply of ammonia, as a source of nitrogen, *limited*, like that derived from the presence of humus in the soil, to a *gain time*."—*Ib.*, p. 74.

What, we would ask, is *gain of time* in the growth of plants, the very essence of the distinction between *natural* growth *artificial* growth, that is, AGRICULTURE? In this admission, erefore, is involved the fullest and most convincing proof, that any of the constituents of plants should have attributed to them *preponderating* value and importance," it should be those which is due a *gain of time*.

To resume: The following is a brief summary of the criticisms to which our experiments on the growth of wheat have been bmitted by Baron Liebig, with the view of showing that their sults are at once consistent with his own peculiar doctrines, d inconsistent with our own conclusions.

He maintains alternately, that the supply of ammoniacal salts s *not*, and *has*, been the source of the increase! And, when it came impossible to avoid the latter conclusion, how does he alify the unpalatable admission?

Such a result is precisely in accordance with what theory teaches!

Salts of ammonia are themselves to be included as mineral anures!

Their action is mainly that of rendering soluble the minerals of e soil, and hence it is the minerals to which at last the increase is e!

If ammonia-salts do give increase, they do but exhaust the land!

Their action is only a gain of time!

And lastly, *their observed effect in our own experiments is only exceptional*, so that no deductions whatever can be formed therefrom, in regard to corn-exhaustion in any other case!

The point which we propose next to illustrate, by reference to a very condensed tabular statement of a large number of experiments is, that the provision of *available nitrogen within the soil* has a very marked effect upon the increased growth of *barley* also—the second in importance of the cereal grains in our own country and climate.

In Table II., given below, we have the results of experiments on the growth of barley in the year 1854, in two separate fields of widely differing previous history. The portion of "*Barn-field*," the produce of which is given in the upper part of the Table, had grown turnips experimentally for ten successive years without being manured with any nitrogenous or carbonaceous substance. It had, however, been exceedingly liberally supplied every year, with various mineral manures; which in some cases included in very large excess every constituent which the ashes of the crop would contain. The condition of these plots, indeed, would be that of such exhaustion of organic substance and, on the other hand, of such a repletion of mineral constituents, as could not occur in the ordinary course of farming. Strange to say, however—that is, for the credit of the "*mineral theory*"—this exceedingly mineral-enriched, and nitrogen-impoverished land, gave for the season in question an excessively meagre crop. In fact, its total produce (corn and straw) was only two-thirds that of our continuously unmanured wheat-plot, and little more than half as much as that grown without manure or by mineral manure alone, in our other experimental barley-field; although the crop in the latter, some of the results of which are also given in the Table, was the fourth of barley, and the third without nitrogenous manure. Previous to the first experimental crop, however, the latter field had not been submitted to more than an ordinary course of exhaustive cropping. We have here, then, a remarkable instance of the utter incapability of a very liberal supply of mineral constituents, on a soil exhausted of organic food, to enable the plant to obtain sufficient nitrogen from atmospheric sources, for the growth of the barley-crop in adequate agricultural quantity. Nor was there in this "*Barn-field*" a difference of more than a bushel or two, between the produce of those plots which had previously received large amounts of alkalies as well as phosphates, and those which had only been manured with the latter.

TABLE II.—*Summary* of Experiments on the Growth of Barley.
Average Total Produce (Corn and Straw) per acre, in lbs.

General Condition of Manuring.	Total Produce.	Total Increase by Nitrogen.
Barn-field—Harvest 1854.		
	lbs.	lbs.
Mineral Series (mean)	2474	...
Ditto (ditto) with Ammonia-salts... ...	7382	4908
Ditto (ditto) with Nitrate of Soda ...	8005	5531
Hoos-field—Harvest 1854.		
Mineral Series (mean)	4656	...
Ditto (ditto) with Ammonia-salts... ...	8127	3471
Ditto (ditto) with Rape-cake...	8150	3494
Nitrate of Soda (second year without Minerals)...	7400	2744

In the Table it is seen, that the mean total produce (corn and straw together) of barley in "*Barn-field*," on the previously mineral-manured plot, is 2474 lbs.; that on land in similar previous condition, but with ammonia-salts now added, is 7382 lbs.; and that with nitrate of soda instead of ammonia-salts, is 8005 lbs.

In "*Hoos-field*" again, the mean total produce of the series manured annually with *direct* mineral manures, is 4656 lbs.; that with ammonia salts in addition, is 8127 lbs.; that with (besides the minerals) rape-cake, equal in its amount of nitrogen to the ammonia-salts of the previous series, is 8150 lbs.; and that with nitrate of soda, this being the second year of its application without mineral manure, is 7400 lbs.

Here then, in both fields, we have an enormous increase of produce in the barley crop, by means of available nitrogen supplied to the soil. And although, owing to the more limited range of the underground feeders of the barley plant, and to the much shorter period of time during which it collects its mineral food, *direct* mineral manures have a more beneficial influence upon that crop than upon wheat, yet it is obvious, that as with the wheat crop so also with barley, a maximum agricultural produce cannot be obtained, however liberal the supply of minerals, unless there be, at the same time, an accumulation of available nitrogen *within the soil itself*.

We now turn to a consideration of Baron Liebig's treatment of our recorded experiments and conclusions in reference to the growth of *turnips*. He says:—

"It seems to me worth while to consider here one more of those unmeaning practical experiences, made by one who is, according to Mr. Pusey, the

first agricultural authority in England, namely, by Mr. Lawes. It refers to the growth of turnips (vol. xii. p. 34, and vol. viii. part ii. p. 26, *et seq.*)"—*Principles*, p. 123–4.

In consequence of the great length of this Paper, we must content ourselves on this occasion with examining only one or two of Baron Liebig's criticisms on this point, in that detail which we had intended.

Baron Liebig attributes to us the assertion, that "phosphoric acid alone was found efficacious" in our experiments—a statement in direct contradiction to opinions strongly insisted upon throughout our Paper on turnip culture, from which in part he quotes. He considers the results obtained by large quantities of burnt bones and sulphuric acid, as demonstrating "the existence of a very unusual quality of soil"; and having thus admitted the fact itself, he adds:—

"But if we inquire into the reason why the credit of this striking result is given to the phosphoric acid, we find that this is a *sheer fancy*. Were any one to assert that, under the circumstances, it was the free sulphuric acid which produced the result, it would be difficult to disprove the assertion, as will be seen from the following calculation."—*Principles*, p. 125.

He then goes on to assume, that we employed in the experiments in question, "as a minimum," 400 lbs. of burnt bones (and sulphuric acid besides), every year, during eight successive years—or in all, 3200 lbs. of burnt bones; more than enough, as he tells us, for fifty average crops of turnips. Now it so happens, that 3200 lbs. of burnt bones *is* a pure assumption of Baron Liebig's, as indeed he admits in a note; but he does not the less on this account make liberal use of this assumed fact. The quantity of phosphate of lime used in the eight years was in reality more than a thousand pounds less than was supposed by Baron Liebig. Further on, after having pointed out the excess of phosphate added in the previous years, he says:—

"It is impossible to believe that the effect, in the seventh year, under these circumstances, can have depended on the newly-added phosphoric acid, as Mr. Lawes concludes."—*Ib.*, p. 126.

And again—

"What conclusion would Mr. Lawes have come to, had he manured his land, for two years, only with phosphate of lime, and had added, in the six succeeding years, 400 lbs. of sulphuric acid alone, and had he thus obtained the same produce, in eight years as if he had used 3200 lbs. of burnt bones?"—*Ib.*, p. 129.

Now it does so happen, that we have an experiment that will show, as far as such a point is susceptible of proof, that there *was* an action due to the large amount of phosphate of lime added to the soil, which could not be attributed to "free sulphuric acid" in admixture with it; and further, that a still greater excess of superphosphate of lime gave a further increment

of increase. In the following Table (III.), we have the result of this experiment; namely, that on plot 21, which, with those on plots 7 and 22, given on either side of it, will illustrate the point in question:—

TABLE III.—Selection of Results of Experiments on Turnips. Produce of Bulb per Acre.

Years.		PLOT 7. ½ Cwt. Sulphate Ammonia, in 1843. 3 Cwts. ground Apatite, in 1844. 12 Cwts. Gypsum, in 1845. Afterwards Unmanured.		PLOT 21. Superphosphate of Lime, in 1843–4–5. Afterwards Unmanured.		PLOT 22. Superphosphate of Lime, *every Year.*	
		Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
Norfolk Whites.	1843	6	18¼	11	14¾	12	3½
	1844	3	1	7	3¼	7	14½
	1845	5	13¾	13	2¾	12	13¾
	1846	...		1	5¼	1	18
	1847	2	11½	3	17	5	11
	1848	1	0½	6	7¼	10	11
Swedes.	1849	0	2½	0	15¾	3	15
	1850	4	6¾	8	0	11	9
	1851	3	10	6	7½	10	16¼
	1852	1	4	2	15½	8	9½
Totals ...		28	8½	61	9	85	1¾
Means ...		3	3½	6	3	8	10½

Plot 21 received in all, during the first three years of the experiment, about 800 lbs. of bone-earth, or its equivalent in apatite (mixed with sulphuric acid); and from that time it was unmanured. And since the whole produce of the ten years would only remove from the land, say one-third, of the phosphoric acid added in the first three years, it is obvious that there must have remained in the soil a large residue of the supplied phosphate, for the seven crops grown since the application of the manure.

Plot 22 had also large amounts of superphosphate of lime supplied to it during the first three years; and after that time it received every year 160 lbs. burnt bones, mixed with 120 lbs. of sulphuric acid of sp. gr. 1·7.

Plot 7, having had a small quantity of ammonia-salts in 1843, 3 cwts. of apatite in 1844, and 12 cwts. of gypsum in 1845, yielded, in 1846, without manure of any kind, so small a crop as not to be worth weighing; and this plot 7 was afterwards continuously unmanured.

It is seen that, during the first three years of the experiment, plots 21 and 22, being both manured liberally with superphos-

phate of lime, gave nearly equal amounts of produce; though plot 22, having rather the most of the manure, gave also rather a higher average produce.

In 1846, the now unmanured plot 7 (which, however, had received a large quantity of powdered apatite two years previously) yielded next to nothing; plot 21, now unmanured, but having a larger residue of phosphate of lime in the soil, and in a more easily soluble form than plot 7, gave 1¼ tons of bulb; and plot 22, with its large residue of phosphate of lime, as well as annual additional supply of superphosphate of lime, gave nearly 2 tons.

In 1847, plot 7 gave rather more than 2½ tons; plot 21, with its residue of phosphate of lime, gave nearly 4 tons; and plot 22, with its *additional supply* of superphosphate, as well as residue, gave rather more than 5½ tons.

In 1848, the comparatively non-residue-plot (7) gave 1 ton of turnips; the residue-plot, 6⅓ tons; and the residue, with additional supply, more than 10½ tons.

In like manner, to the end of the experiment, it is seen that the residue-plot 21 always gives a considerable increase (varying according to season) over the comparatively non-residue plot 7; and again, plot 22, with both its accumulating residue and its additional supply, in every case gives a considerable increase over the residue plot 21, although the latter, even up to the last year of the experiment, still retained a large proportion of the previously added phosphate, besides all that must have been available, during the ten years, from the stores of the soil itself.

Now it is quite certain, that on plot 7 there was much more phosphate supplied in the apatite in 1844, and derivable from the annually available stores of the soil, than was necessary to supply with phosphoric acid a much larger produce than was obtained on that plot. It is also quite certain, that the much larger produce on plot 21 than on plot 7 must have been due to the residue of the manuring of the years 1843–4–5. If any one, therefore, were to assert that, under the circumstances of this plot 21, "it was the free sulphuric acid which produced the result," it would certainly *not* "be difficult to disprove the assertion." And again, it is certainly also true, that the further increase obtained on plot 22 over plot 21 must be due to the additional mixture of phosphate of lime, mixed with sulphuric acid, which was annually supplied to it. And, as we have seen that on plot 21, a supply of phosphate far in excess of that contained in the crop produced—the action of which could *not* be attributed to *free sulphuric acid*—*did* give an increase, and as we well know that any free sulphuric acid which might reach the soil would in a very short time be neutralised, the reader will

judge for himself, whether on plot 22 the increased produce obtained was more probably due to free sulphuric acid, or to the still greater excess of phosphoric acid or its compounds supplied in the manure;—that is to say, whether the increased produce on plot 22 was not due to an action very similar in kind to, but differing in degree from, that on plot 21?

Again, Baron Liebig says--

"If we continue our examination, we shall find, still in his own experiments, much more convincing proofs that the excess of phosphoric acid cannot have been the cause of the increased produce."—*Principles*, p. 126.

He then goes on to institute comparisons which, taking the figures simply as they stand, and without the explanations of the very results in question given in our papers, were certainly well calculated for his purpose, if the only object he had in view were to mystify, misrepresent, and fix contradiction upon agricultural phenomena. Thus, following up the incorrect assertion that "phosphoric acid alone was found efficacious" in our experiments, by assuming that we should measure the action of farm-yard manure or rape-cake, by the quantity of phosphoric acid or phosphate of lime they contained, he goes on to compare the produce by these manures, sometimes in the same year, and sometimes not, with that by superphosphate of lime alone; and then he says, in regard to these results, "in what incomprehensible contradiction do they stand to the opinions of Mr. Lawes!" One quotation alone from our paper, to which, indeed, but for the length of this article, we had intended to add many more, will show not only whether we maintained that *phosphoric acid alone was efficacious*, but whether or not it was to the phosphoric acid they contained, that we supposed the action of farm-yard manure and rape-cake was chiefly or only due.* Thus we say, speaking of superphosphate of lime—

* As a further instance of the spirit and fairness of Baron Liebig's criticisms, he speaks of the "unpardonable blunder" of using rape-cake as a carbonaceous manure,—because, as he says, it contains a large amount of nitrogen also; on which point he quotes the analyses of Mr. Way. Those who have not read our Papers, would scarcely think it possible, that we have again and again spoken in them of the amount of nitrogen in rape-cake; and frequently also, particularly contrasted the effects of rape-cake and other organic manures, with that of ammonia-salts, in order to eliminate the action of the nitrogenous and carbonaceous supply respectively. But, Baron Liebig equally ridicules us, for using experimentally, *rice* and *oil*: substances chosen as containing little or no nitrogen. One of the carbonaceous manures by which he obtained his results, was sawdust. His anxiety to ignore that we attribute an action to carbonaceous manures, and to ridicule all our experiments connected with such manures, is however perfectly intelligible, when it is borne in mind, that he claims to have embodied in his "14th Proposition," a *correction* and *enlargement* of his views. That Proposition is, he says, the only one of the 50 given in his '*Principles*,' the substance of which is not to be found in his previous works; and the object of that Proposition is to claim an action of animal and vegetable manures, by virtue of the *organic substance* they contain. We shall however have occasion to show, in one striking instance at least, and we could

"The latter manure is the form which is found to produce the greatest effect upon the young plant, and especially upon the development of a large amount of fibrous roots. . . . . *It must, however, be clearly understood that the bulk of an agricultural crop of turnips depends materially upon the amount of organic matter contained in the soil, without which the development of the power of growth by means of the phosphate will be unavailing.* . . . *Rape-cake, as containing a large amount of organic matter, is an admirable manure for the turnip as a substitute for farm-yard dung.*"—*Jour. Roy. Agric. Soc. Eng.* vol. viii. part ii. pp. 562–8.

We cannot now stop to point out various little discrepancies in Baron Liebig's professed quotations of figures; but there is one result, which he says is "still more incomprehensible," to which we must call attention. In this particular instance, we cannot entirely blame Baron Liebig, for it is a *misprint* in our own paper, that has supplied him with the strong point of his case; though, the evidence respecting the same experiment given in the immediately succeeding tables, would have saved any careful critic, from the blunder into which he has been led by the misprint. He quotes a plot manured with gypsum and rape-cake in 1845, and apparently yielding 18 tons 1 cwt. of turnips. Now it so happens, that in our paper, we spoke of the produce of the farm-yard manure of that year, which was 17 tons, as the highest in the entire series of the experiments. This certainly ought to have raised some doubt as to the correctness of the figures in question. The fact is, that instead of 18 tons 1 cwt. the produce was only 10 tons 1 cwt.; and this was shown by the relation of the average weight of bulbs and number of plants per acre, and by that of the acreage produce of leaf, and the proportion of the latter to 1000 of bulb, as given in the tables which immediately succeeded.

To say nothing of minor discrepancies which also appear, the following is the curious contrast which we obtain, between Baron Liebig's comment, and that which is really consistent with the facts of the case. In the left-hand column is given Baron Liebig's comment, founded on the misprint; and in the right-hand one, the comparison is shown as it *would be*, according to the corrected figures. The italics are given to indicate the differences between the parallel passages in the two cases.

Principles, p. 127–8.	*Amended Comparison.*
"In 1845, another lot of equal size, manured with 12 cwt. of gypsum (the residue of the manufacture of tartaric acid), and 10 cwt. of rape-cake, yielded 18 *tons* 1 *cwt.* of turnips, that is, 6 *tons more* than the highest produce (12 *tons*) of the land	In 1845, another lot of equal size, manured with 12 cwt. of gypsum (the residue of the manufacture of tartaric acid), and 10 cwt. of rape-cake, yielded 10 *tons* 1 *cwt.* of turnips, that is, 3 *tons* 1¾ *cwt. less* than the highest produce (13 tons 2¾ cwt.)

in others, that 'Proposition 14' is not the only one, which records an advance upon Baron Liebig's previous views.

manured with bones and sulphuric acid, and *nearly* 10 *tons more* than its average produce, or *more than double* of this last, which was 8¼ tons."

of the land manured with bones and sulphuric acid, and *only* 1 *ton* 16 *cwt. more* than its average produce, which was 8¼ tons. *But, gypsum without rape-cake gave* 7 *tons* 9 *cwt. less than the highest by superphosphate of lime in the same year; and* 2 *tons* 11 *cwt. less than the average produce of the latter!*

Baron Liebig's numerical comment on this "still more incomprehensible" result is therefore *simply reversed.* But let us now see how far his comparison was legitimate, even supposing his numbers had not been erroneous. The real fact was, then, that gypsum used *alone*, though even after apatite (phosphate of lime) in great excess in the previous year, gave only 5 tons 14 cwt. of produce. *This*, as the result of purely mineral manure, was that which, *in fairness*, should have been compared with the "12" or rather 13 tons 2¾ cwt. yielded by the phosphate of lime and sulphuric acid in the same season. Again, 7 tons 10 cwt. was the produce of 10 cwt. of *rape-cake, when used alone;* and when to this latter amount is added, that portion of the 5 tons 14 cwt. by gypsum alone, which may be supposed not to be due to the previous dressing of finely powdered apatite, there is certainly nothing anomalous in the fact, that the gypsum and rape-cake together, gave 10 tons 1 cwt. of turnips.

It is, then, after such comparisons as those which we have pointed out, and on an incorrect statement as to our conclusions, that Baron Liebig says of our results, "In what incomprehensible contradiction do they stand to the opinions of Mr. Lawes!" And he adds—

"It is out of the question, after the facts just related, to assume that the excess of phosphoric acid was necessary, and was the cause of the increase. Is it then the sulphuric acid, the lime, or both together (gypsum), or is it the organic matter in the stable manure and in the rape-cake?"—*Principles*, p. 129.

To this we answer—that, *where the superphosphate of lime was used*, "it is out of the question after the facts just related," *to doubt*, that the action of "the excess of phosphoric acid," or of the phosphate of lime, "was the cause of the increase," *in that particular case!*—or, that *where the farm-yard manure or rape-cake was used*, "the organic matter in the stable-manure and in the rape-cake," together with the mineral constituents they contained, played an important part in providing the actual substance of the increased crop.

What, then, is the result of our examination of Baron Liebig's criticism on our experiments and conclusions regarding the growth of turnips? It is seen—that his statement of our general conclusion is *incorrect;* that his allegation as to the amount of phosphate

of lime we used is *an assumption and erroneous;* that his objections to admitting an action by an apparent excess of phosphates are *captious and unfounded;* that his "incomprehensible" facts are *comprehensible and consistent;* and that his "still more incomprehensible" fact is not even a fact at all, but is founded only on an easily discoverable *misprint!*

But after all this strenuous resistance of the notion, that in the *agricultural*—that is, in the *artificially enhanced*—growth of plants, there may be required a supply of substances by manure, beyond that which can be accounted for by any idea of merely supplying what is to become an actual constituent of the removed crop—and saying with regard to it, "have we made, after all, but a hair-breadth's progress from our old position?"—we find, but a page or two further on, the enunciation of a general principle, obviously intended to cover any such instances which it may be impossible to deny the existence of as facts. Baron Liebig says:—

"As a general rule, the manuring of a field *should not be calculated from the sum total of the mineral ingredients which the plant takes from the soil, but must be proportional to that maximum of these substances which is required by the plant in a certain period of its growth.*"—*Principles*, p. 133 (note).

We would compliment Baron Liebig on the fact, that we have here evidence of more than "a hair-breadth's progress from our old position," when we contrast that which is herein involved, with his general conclusions on the subject of manuring, in summing up his *general retrospect*, in the fourth and last edition of his main work, where he says:—

"By an exact estimation of the quantity of ashes in cultivated plants growing on various kinds of soils, and by their analysis, we will learn those constituents of the plants which are variable, and those which remain constant. Thus also we will attain a knowledge of the quantities of all the constituents *removed from the soil by different crops.*

"The farmer will thus be enabled, like a systematic manufacturer, to have a book attached to each field, in which he will note *the amount of the various ingredients removed from the land in the form of crops, and therefore how much he must restore to bring it to its original state of fertility.* He will also be able to express in pounds weight, *how much of one or of another ingredient of soils he must add to his own land, in order to increase its fertility for certain kinds of plants.*"—*4th Edition*, p. 212, 213.

And then again, to cover by general principle, the undoubted fact, that the resultant requirements of land under cultivation, are certainly not to be ascertained by the consideration of the collective mineral composition of the crop to be grown, we are told:—

"The produce of a field stands related to the amount of that mineral ingredient which its soil contains in *smallest quantity.*"—*Principles*, p. 133 (note).

And this simply common-sense notion (provided that smallest quantity be too small for the requirements of a maximum growth)

but which, however, is the clear way of escape from his previous applications of his doctrines, and a net large enough to include many now established facts inconsistent with those applications, is insisted upon much more at length in Baron Liebig's recent reply to the criticisms of his "Principles" by Professor Wolff.

In like manner, the careful reader will observe throughout all Baron Liebig's writings in this discussion, that, whenever there is a fact to be admitted, or a deviation from the exact expression previously given to his views to be conceded, we are first favoured with a general or abstract statement; perhaps obviously true, and perhaps so little differing from previous forms of expression in individual sentences of his works, as to pass unobserved, and yet sufficient to claim the fact or conclusion which he has to record and admit, as but an obvious consequence. The following is a further illustration of this mode of ignoring the experimental evidence and conclusions of others, and of netting the whole as an obvious consequence from his own principles.

The reader need scarcely be reminded of Baron Liebig's argument on Boussingault's rotations, viz., that the nitrogen of his manure had done nothing; and that if the latter had been burnt, and its nitrogen expelled, the produce would have been the same;—that, in defining agriculture as distinguished from normal vegetation, he has said, that the nitrogen yielded to the latter by the atmosphere was "*quite sufficient for the purposes of agriculture*";—and that, speaking of produce grown under cultivation, that is, in agricultural quantity, he has said—"Surely the cerealia and leguminous plants which we cultivate must derive their carbon and nitrogen from the same source whence the gramineæ and leguminous plants of the meadows obtain them!" But what are we *now* told? And how is the very opposite of this, the clear recognition of which we have maintained to be the very key to advancement in agricultural science, now swept into accordance with Baron Liebig's own principles by general and abstract statements, obviously true, and put apparently with little reference to any point in dispute?

"But the *quantity* or amount of produce is in proportion to *two factors*, namely, the *atmospheric* food of plants, and their *terrestrial* or *mineral* food. This quantity depends on the presence of both, and on their co-operation in due proportion, and in the proper time.

"If the amount of one of these factors—*the mineral food of plants*—be increased, while that of the other—the *carbonic acid and ammonia*, which can be conveyed to the plants by means of the atmosphere—remain unchanged, the amount of carbonised and nitrogenised produce cannot thereby increase; but the crops, in this case, will vary with the absorbing or active surface of the plants cultivated on the land."—*Principles*, p. 76.

He then goes on to state that "the air contains a very limited amount of carbonic acid and ammonia," and that—

"It is obvious that, if we could double or treble the proportion of carbonic acid and ammonia in the air, the plants would, in the same circumstances, take up twice or thrice as much carbonic acid and ammonia in the same time, or as much as they could do in the normal condition in twice or thrice the time."—*Ib.* 77.

Here, then, we are told, that the supplies of carbonic acid and ammonia in the atmosphere, though enough for *normal vegetation*, are "very limited." Surely, however, they still remain as before, "*quite sufficient for the purposes of agriculture*"? Baron Liebig answers this question thus:—

"But the weight or amount of the crops is in proportion to the quantity of food of both kinds, *atmospheric* and mineral, which is *present in the soil* or conveyed *to it* in the same time. *By manuring with ammoniacal salts soil rich in available mineral constituents, the crops are augmented in the same way as they would have been if we had increased the proportion of ammonia in the air.*"—*Ib.* 77, 78.

How neatly, then, has Baron Liebig here begged the whole question of the necessity in *agriculture* as distinguished from natural vegetation, of an accumulation of available nitrogen *within the soil itself!* How curiously, too, are the very circumstances, under which we have previously been told that our crops are the *most* capable of relying upon the atmosphere for their nitrogen—namely, those of *mineral richness—now* made the very conditions under which the supply of ammonia to the soil is *most necessary!* Thus, speaking of the supply of ammonia, he had *before* said—

"that it may be even superfluous, *if only the soil contain a sufficient supply of the mineral food of plants*, when the ammonia required for their development will be furnished by the atmosphere."—*4th edition*, p. 212.

And again:—

"If the soil be suitable, *if it contains a sufficient quantity of alkalies, phosphates, and sulphates*, nothing will be wanting; the plants will derive their ammonia from the atmosphere as they do carbonic acid." (!)—*Translation of Letter, Farmer's Magazine*, vol. xvi. p. 511.

But not only does Baron Liebig do this, but he claims it as the established principle of his previous writings, that it is for "*wheat*" distinctively, that ammonia must be added in the manure. Thus he goes on to say:—

"This is the meaning of the passages above quoted from my work, which tell the agriculturist that, in order to raise the produce of his land above a certain point, in the case of such plants as have not many leaves—*for example, of wheat*—he must add ammonia in the manure."—*Principles*, p. 78.

Here, then, the importance of nitrogen in the soil for *wheat*, as distinguished from other crops, is claimed as a conclusion established by "the passages above quoted." But strange to say, after thus attempting to claim that which is now so far an established fact, that it would be only ridiculous to deny it,

Baron Liebig in the very next page, when the object is to refute our statements, and not to claim the truth as his own, says:—

"It is not easy to understand how Mr. Lawes could deduce from his results the conclusion, '*that nitrogenised manures are peculiarly adapted for the culture of wheat*,' . . . ."!

Now, it so happens, that in "the passages above quoted," not one word was said of such plants as have not many leaves ——"'for example, of *wheat*." The reference was to *annuals generally*; and runs thus—"The food contained in the atmosphere does not suffice to enable *these plants* to obtain their maximum of size in the short period of their life." These plants, *the annuals*, include of course equally "*cerealia* and the *leguminous plants which we cultivate*," of which Baron Liebig has told us, that surely they "must derive their carbon and nitrogen from the same source whence the gramineæ and leguminous plants of the meadows obtain them." But notwithstanding that Baron Liebig has told us in so many forms in his previous works, that the nitrogen supplied by the atmosphere is sufficient for the purposes of agriculture, and also that the *cereals* and leguminous crops of our rotations are equally independent of nitrogen in the soil with the meadows, he now tells us that his meaning in those previous works was, that—for the growth of certain plants—"for example, of *wheat*"—the agriculturist must add ammonia in the manure! The reader will judge for himself then, how far it is candid, or just, or strictly consistent with truth, that Baron Liebig should now seek to include by a statement of general principles, and by stretching and explaining the meaning of individual sentences of his previous works, facts and conclusions since established; and which are not only *fundamental*, as leading to the true explanation of the main features of agricultural practice, but which are further flatly contradicted by other individual sentences of his works, and are, by the concurrent testimony of every competent writer on the subject, inconsistent with the *main, prominent, and most characteristic features*, of his previously promulgated doctrines?

Another instance of this kind will come to light, in considering Baron Liebig's comments on that part of our criticism of his views, which led to the attack on our experiments and conclusions in reference to the growth of turnips. In one of our papers we had said:—

"But it is at any rate certain that phosphoric acid, though it forms so small a proportion of the ash of the turnip, has a very striking effect on its growth when applied as manure; and it is equally certain that the extended cultivation of root crops in Great Britain cannot be due to the deficiency of this substance for the growth of corn, and to the less dependence upon it of the root crops, as supposed by Baron Liebig."—*Jour. Roy. Agr. Soc. Eng.*, vol. xii., part i. p. 35.

This comment we had made in reference to a sentence in Baron Liebig's "Letters," wherein, speaking of the exhaustion of phosphate of lime and alkaline phosphates, by the sale of flour, cattle, &c., he says:—

"It is certain that this incessant removal of the phosphates must tend to exhaust the land and diminish its capability of producing grain. The fields of Great Britain are in a state of progressive exhaustion from this cause, as is proved by the rapid extension of the cultivation of turnips and mango-wurzel—plants which contain the least amount of the phosphates, AND THEREFORE REQUIRE THE SMALLEST QUANTITY FOR THEIR DEVELOPMENT."—*Letters*, 3rd edition, p. 522.

On this sentence we further commented thus:—

"Now, we do not hesitate to say that, however small the quantity of phosphates *contained* in the turnip, the successful cultivation of it is more dependent upon a *large supply* of phosphoric acid in the manure than that of any other crop."

Baron Liebig thus meets these comments,—

"No one surely can believe that my statement as to the very small proportion of phosphates in turnips is untrue, *because* Mr. Lawes has misunderstood the meaning of the sentences above quoted from my work. My remarks had no reference whatever to the manuring of turnips, but were designed to direct attention to the difference between turnips and other crops which require in certain periods of their growth more phosphates than turnips do. With reference to the cultivation of grain, I wished to show that the growth of turnips had acquired so vast an extension [the italics are Baron Liebig's own], *for this reason*, namely, *because the soil loses so little of the phosphates by the cultivation of the latter crop*. Turnips are so advantageous in the rotation, only because, whatever be the quantity of phosphates contained in the soil, or added to it in the manure, they leave in the soil so large an amount of these indispensable salts for other crops, which require a large supply of them."—*Principles*, p. 131.

Further on, Baron Liebig refers the reader to the letter in question, to justify the meaning which he has now given to his sentence, and to convince him that we do not do him justice. Now we must say, that we have carefully re-perused the letter; and still maintain, not only that if language has any meaning at all, we *have* done Baron Liebig entire justice in the interpretation of his sentences which we have given of them, but that, by no interpretation of language, can the meaning which he now claims be given to his argument as formerly put forth. Certainly nowhere have we previously been told by Baron Liebig that—

"Turnips are so advantageous in a rotation only because *whatever be the quantity of phosphates contained in the soil, or added to it in the manure they leave in the soil so large an amount of these indispensable salts for other crops* which require a larger supply of them."

Baron Liebig's statement was, not only that turnips were "plants which *contain* the least amount of the phosphates," but that they "*therefore* require the smallest quantity for their develop-

ment." Whereas our own statement is, that, however small the amount of phosphates *contained* in a removed crop of turnips, they *require a large amount for their development.* And if it be really a well-established fact, that, however small may be the quantity of phosphates lost to the farm by the growth of turnips, still a much more liberal supply is required in the soil for the production of a full agricultural crop of them than of corn, it is then obviously impossible, that the progressive exhaustion of the phosphates, could be the cause of the extended cultivation of the former. In fact, there can be no doubt, that such an exhaustion would be a far greater obstacle to the extended growth of roots than of corn.

But with regard to the effects of an artificial supply of phosphates, upon the increased production of corn, Baron Liebig further says :—

"We believe that the importation of 1 cwt. of *guano* is equivalent to the importation of 8 cwt. of wheat; the hundredweight of guano assumes in a time which can be accurately estimated, the form of a quantity of food corresponding to 8 cwt. of wheat. The same estimate is applicable in the valuation of bones.

"If it were possible to restore to the soil of England and Scotland the phosphates which during the last fifty years have been carried to the sea by the Thames and the Clyde, it would be equivalent to manuring with millions of hundredweights of bones, *and the produce of the land would increase one-third, or perhaps double itself, in five to ten years.*

"We cannot doubt that the same result would follow *if the price of the guano admitted the application of a quantity to the surface of the fields, containing as much of the phosphates as have been withdrawn from them in the same period.*"—*Letters,* 3rd edition, pp. 523, 524.

How far the increase in the produce of wheat by the use of *guano,* is measureable by the amount of *phosphates* it supplies, the practical farmer may judge from the fact, to which we have before called attention, namely, that 1 *cwt. of Peruvian guano will supply as much phosphoric acid* as would be contained in about 18 *bushels of wheat and their equivalent of straw, say* 1800 *lbs.;* and that of *nitrogen,* 1 cwt. of guano will contain *about as much as* 11 *bushels of wheat and* 1100 *lbs. of straw.* But, if we were to assume, that one-third to one-half only, of the nitrogen supplied in manure for the growth of wheat will be obtained in the increase produced, we should have on this calculation, 4 or 5 bushels of corn, and their equivalent of straw, by the use of 1 cwt. of guano. We leave it with the practical man to judge, whether these last amounts, or 18 bushels of corn with their equivalent of straw, are more nearly those which in practice he obtains, by the use of 1 cwt. of guano.

Baron Liebig proceeds :—

"If a rich and cheap source of phosphate of lime and the alkaline phosphates were open to England, there can be no question that the importation

of foreign corn might be altogether dispensed with after a short time. For these materials England is at present dependent upon foreign countries, and the high price of guano and of bones prevents their general application, and in sufficient quantity. Every year the trade in these substances must decrease, or their price will rise as the demand for them increases.

"According to these premises, it cannot be disputed, that the annual expense of Great Britain for the importation of bones and guano is equivalent to a duty on corn: with this difference only, that the amount is paid to foreigners in money."—*Letters*, 3rd edition, p. 524.

Now, that the efficacy of guano for the production of corn, measurable by the amount of nitrogen, and not by that of the phosphates which it contains, is obvious from the simple facts,—that guano rich in nitrogen and relatively poor in phosphates will command twice the price of one rich in phosphates and poor in nitrogen,—and that all experience shows, that the dear guano, rich in nitrogen and relatively poor in phosphates, yields a far greater increase of grain, than that which is cheaper and contains more of phosphates and less of nitrogen. But, with regard to Baron Liebig's supposition, that if a rich and cheap source of phosphates were open to England, we might soon be independent of foreign corn,—since we now have such a source, this opinion is worth a little examination. It is probable, that from 20 to 25 per cent. of the corn consumed in this country, is imported. Unless, therefore, a very much larger breadth of land were brought under corn, it is obvious that, to attain this happy result, the whole of our wheat-fields must yield from one-fourth to one-third more produce than at present. Whether or not it is likely that they would do so by the use of *phosphates*, even if mixed with alkalies, provided that available nitrogen were not at the same time added, the results not only of our own experiments, but the experience of every farmer who has ever used an artificial manure, will at once decide.

Fourthly. We proceed to illustrate, by condensed summaries of an immense mass of experimental results, and a very rapid consideration of their indications, some prominent points connected with the action of manures on the different crops of rotation, and with the chemical circumstances involved in fallow and a rotation of crops itself. The first of these points, namely the characteristic action of certain constituents of manure, upon the most important crops grown in our rotations, is illustrated in Table IV. which follows; and, for the purpose in question *wheat* and *barley* have been selected as cereals; *turnips* as *root-crop*; and beans and clover as leguminous crops.

TABLE IV.

Summary—showing the characteristic action of Manures on different Crops. Average Increase of Produce per Acre.

Constituents of Manure (used separately or combined).	Cereals.				Leguminous Crops.		Roots.	
	Wheat.			Barley.	Beans.	Clover	Turnips.	
	Woburn.	Holkham.	Rothamsted.					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	tons.	cwts.
1. Potass	..	..	..	..	938	1017	..	
2. Potass, soda, and magnesia	..	..	270	none.	843	1221	..	
3. Superphosphate of lime	..	..	414	242	none.	113	7	1¼
4. Do. do. and potass	..	..	97	..	503	1580	5	8
5. Nitrate of soda	..	..	2332	1870	..	..	..	
6. Ammonia salts	1640	1442	1714	2317	14	none.	0	6¼
7. Ammonia salts and superphosphate of lime	..	..	2511	2828	175	none.	8	15¾
8. Ammonia salts, potass, and superphosphate of lime	..	..	2956	..	850	1086	9	16¼
9. Ammonia salts, potass, soda, magnesia, and superphosphate of lime	1757	2357	3035	3154	1367	925	10	12¾

Each entry in this Table (IV.) indicates the average *increase* per acre, calculated from all the eligible cases, throughout the entire series of experiments with the different manures and crops, and extending in most cases over several seasons. The method of the estimation is as follows:—namely, to find the *increase* in each case, or average of a number of cases, occurring in any particular season, by deducting from the total *produce* by any particular constituent or constituents of manure, that obtained without manure in the same season; and an annual average is then taken of the increase thus obtained for the several seasons.

In such a summary as is here given, we cannot expect exact numerical consistency in apparently similar cases, the results being frequently the average of very different seasons; but we cannot fail to find prominent indications of the broad and characteristic effects of the respective manurial constituents or combinations on the respective crops. And, since in all cases (unless otherwise mentioned) the indications are derived from the growth of the crop in the manner described through several consecutive seasons, the *characteristic* exhaustion or requirements of the several crops, is thus very prominently brought to view.

The manurial conditions enumerated in the first column of the Table, may be further explained, thus:—

Potass, soda, and magnesia—generally as sulphates.

Superphosphate of lime—bone ash, mixed with water, and decomposed by three-fourths of its weight of sulphuric acid, sp. gr. 1·7.

Nitrate of soda—commercial.

Ammonia-salts—generally an equal mixture of the sulphate and muriate.

As already stated, the crops brought into this review, are wheat, barley, beans, clover, and turnips. In the case of wheat, barley, and beans, the figures represent the *total* increase, including both corn and straw; in that of clover the increase is given for the sake of comparison, in somewhere about the same state of dryness as the corn crops, that is, to the weight of the *dry matter*, one-sixth is added for water; and that of turnips includes both leaf and root in the fresh state as weighed.

At an earlier page, we have called attention to the fact, that Baron Liebig being obliged to admit the influence of nitrogenous manures in yielding an increase in wheat in the experiments on our own land, asserts that such a result is simply exceptional; and that from it no conclusion can be formed as to what would happen on any other lands of different quality. On this point he says:—

"Had Mr. Lawes asserted that on his land, in the given circumstances, ammonia and ammoniacal salts were found to be peculiarly favourable to the growth of wheat; and that, leaving the price out of view, these salts, under similar circumstances, formed the best manure, he would simply have confirmed a result predicted by theory. But even if his assertion had been given as an entirely new discovery, there could have been nothing urged against it.

"If, however, we extend his conclusions to any other land of different quality, and placed in different preliminary conditions, it will appear entirely erroneous; for it can be proved, in the same way, and by facts equally decisive, that ammoniacal salts alone, in thousands of wheat-fields, do not in the smallest degree increase the produce; and that, in thousands of other such fields, these salts do increase the produce for a year, or for two years, and that then a farther application of them to the same land is found to be utterly without effect."—*Principles*, pp. 79, 80.

"The results of Mr. Lawes have no value for his next-door neighbour, nay, they have no value for himself; for the *recipe*, to which he comes, only applies to his own lands, and to them only in so far as experimented on, and only for a very limited number of years."—*Ib.*, p. 105.

"It is altogether incomprehensible that it should never for one moment have occurred to Mr. Lawes, that in Germany, France, and even England, all land has not the quality of his land."—*Ib.*, p. 120.

Now we have already shown, that whatever the natural quality of our own land, and whatever the amount of its annual produce under the influence of natural soil and season supplies, it was nevertheless, in an agricultural sense, in a state of corn-exhaustion, induced by the growth of a succession of crops in the ordinary course of farming, but without receiving any manure after the commencement of the course. It was, indeed, brought into such a state, that its produce was very far below that which might have been obtained by the ordinary means of restoration. We further maintain, that the nature of the exhaustion which the results of these experiments showed our field to have un-

dergone, is precisely that which all experience shows (and we have perhaps opportunities of information on this point second to none) to be the *characteristic* exhaustion induced by the growth of grain in an ordinary course of rotation with home-manuring. Upon the truth of this statement, which no results of direct experiments on individual soils would, we suppose, be admitted to substantiate, we are content to rest the credit and validity of our conclusions generally. More than this, however, as insinuated by Baron Liebig,—namely, that we would recommend the application of ammonia-salts alone, on all soils, and for the continuous growth of corn as an agricultural practice—*we have never done.**

Some of the results in Table IV. will, however, distinctly show, that the "recipe," as Baron Liebig calls it, to which we come, is not only applicable to our "own lands, and to them only in so far as experimented on," but that this so-called "recipe" is applicable to "other land of different quality." Thus, under the head of *wheat*, we have in the Table the results obtained by the use of ammonia-salts, both used alone and with a full supply of minerals, not only on our own land, but on that of the Duke of Bedford at Woburn, and of the Earl of Leicester at Holkham; and, as will be seen by the description given below, the character of the soil in these two cases differed very widely, both from each other, and from our own. In some particulars, indeed, especially at Woburn, the description of land is such, that if it were possible to get from any ordinary cultivated soil, a result inconsistent in the main with our own, we should, according to the notions of Baron Liebig, be led to anticipate that it would be here most manifest.

The soil upon which the experiments at Holkham were made is described by Mr. Keary, as a "light, thin, and rather shallow brown sand-loam," but "resting upon an excellent marl, which contains a large quantity of calcareous matter." Mr. Keary adds, that he finds these light sand-loams, *with the above subsoil*, "to be most productive and grateful for *high-farming*."

Mr. Baker describes the land allotted to the experiments at Woburn as follows:—

"The land these experiments are upon is what I consider a very poor description of *sand*, on a particularly wild sandy subsoil. . . . The land has been farmed on the four-course system, I think I may say for twenty-five years, and previous to that was open heath-land. This, as you are aware, is the *fifth season the plots have had wheat upon them in succession.*"

Now, if it were possible to find a soil under ordinary culti-

* On this point, see Report of Experiments on the Continuous Growth of Wheat at Holkham Park Farm, in the last number of the Journal of the Royal Agricultural Society.

vation, which, according to the suppositions of Baron Liebig, would not give an increase of wheat by the use of ammonia-salts alone, and that would, after one or two years, be strikingly benefited by the application of mineral manures, it would be such a one as has been last described. Let us see what are really the facts of the case.

By the use of ammonia-salts alone, an average total increase was obtained of corn and straw, per acre, at Woburn of 1640 lbs., at Holkham of 1442 lbs., and at Rothamsted of 1714 lbs. And when to the ammonia-salts a liberal supply of minerals was added, the total increase was at Woburn 1757 lbs., at Holkham 2357 lbs., and at Rothamsted 3035 lbs.

As the seasons in which these results were obtained were not the same in all the three cases, no precise quantitative comparisons can be made. But it is a curious fact, that the soil at Holkham, which is described as having at any rate a good subsoil, was more benefited by the addition of a full supply of mineral constituents, than that at Woburn. And again, the soil at Rothamsted, assumed by Baron Liebig to be so exceedingly rich in minerals, gave a greater increase by the combination of *minerals* with a large supply of nitrogen, than was obtained in either of the other cases.

It is established, then, by direct experiment, that the "recipe" to which we come, is not applicable *only* to our "own lands, and to them only, in so far as experimented on." And also, that if we extend our conclusions to "other land of different quality," they are *not* necessarily "entirely erroneous."

Let us now again refer to Table IV., and contrast the effects of characteristic constituents, or combinations of manure, upon some of the most important of our agricultural crops; which stand in relation to each other, in very different positions in our rotations.

We may first premise, that owing to the great liability to disease in the leguminous crops, *especially when grown continuously*, the final produce in their cases, was frequently much less than it promised to be in the earlier stages of growth. The results relating to beans, are in all cases the averages of several seasons; and those in regard to clover, apply to the years 1849, 1851, and 1852, wheat being the crop in the intermediate year; and, as will readily be understood, the produce in the last two years, was both meagre and irregular as compared with that on the same plots in 1849, in which season the crop was very large. For the sake of comparison with the other crops, the clover is given as before stated in about the same state of dryness as the beans and grain; that is to say, the figures in the Table represent the *dry substance*, *plus* one-sixth of its weight of water.

It will be observed, that with a manure of *potass* alone, the

leguminous crops (beans and clover) give a very considerable
rage increase; though in individual years, it was very much
ater than this Table of averages merely, would indicate.
A mixture of *potass*, *soda*, and *magnesia*, gave with wheat a
all average increase; with the other cereal, barley, there was,
ing the average, a slight deficiency. But, with beans and
ver, the supply of alkalies again produced a considerable
rease.
Superphosphate of lime has given with the cereals a small ave-
e increase; with beans on the average there was a deficiency;
h clover a very small increase; but with *turnips*, an average
rease of total produce, of more than 7 tons.
When to the *superphosphate of lime*, *potass* is added, we get
rcely any increase with wheat; a notable increase with beans,
ugh less than when the potass is used alone; a very consider-
e increase with clover; and with turnips, a considerable
ugh less amount of average increase than when the super-
sphate of lime was used without the potass.
Nitrate of soda gives with both the cereals, a very considerable
rease.
Ammonia-salts also gave with both the cereals a large amount
increase; and in the case of wheat a large increase was ob-
ned in other soils of very different quality, as well as at
thamsted. These ammonia-salts, however, which with the
nparatively speaking deficiently nitrogenised cereals, give
h a large amount of increase—with the highly nitrogenous
uminous crops, give in the case of the beans an average of
ly 14 lbs. of increase, and with the clover an actual deficiency.
d with turnips, we have with ammonia-salts alone, only a few
ndredweights of increase, instead of more than as many tons
th superphosphate of lime.
The mixture of superphosphate of lime, with a large amount
ammonia-salts, gives a greater increase with both wheat and
rley, than the ammoniacal salts alone. With the leguminous
ops, the mixture of ammonia-salts and superphosphate of lime,
elds scarcely any beneficial result; indeed with clover there was
the average a deficiency. It should be stated, however, that
ving to the even injurious effects observed on the use of much
nmonia-salt with the leguminous crops, the quantities employed
r acre in the cases in question, were much less than with the
reals. In the turnip experiments, also, much less of these
lts was found to be appropriate than in the case of the grain
ops, and less therefore was employed. But, although when
ed alone, the ammonia salts gave no appreciable result
ith turnips, yet, when mixed with superphosphate of lime, they
creased the efficacy of the latter manure. Thus, we have with

the mixture 8¾ tons of increase of gross produce of turnips, instead of only about 7 tons with the superphosphate of lime alone.

The addition of *potass*, to a mixture of superphosphate of lime and ammonia-salts, gives a still further increase in the case of wheat. With the leguminous crops we have now again a striking increase, and with turnips also a considerable one.

Lastly,—a mixture of ammonia-salts, and a liberal mineral manure, containing superphosphate of lime, potass, soda, and magnesia, gives a very large increase with every one of the crops enumerated. The efficiency of a full supply of minerals, is seen to be very marked even with the cereals, when mixed with a large amount of the ammonia-salts; that is to say, when these crops (the cereals) are supplied, at the same time, with such an amount of *available nitrogen in the soil*, as, when used alone, gives a produce nearly equal to that which would usually have been obtained in the ordinary course of farming. The mixture of ammonia-salts with minerals does not, however, with the leguminous crops, give obviously more increase than when the minerals, and especially the *alkalies*, are used alone. And again, the result upon the *turnips*, of this full manuring—supplying as it does every important constituent except carbon—shows that which we have elsewhere so prominently maintained, namely, that however much the healthy growth of that crop may be increased by the direct use of *mineral*, and especially of *phosphatic* manures, yet that for the production of a full crop, *a supply within the soil of matter for organic formations* is quite essential. And, had we further extended the plan of our Table, so as to show the effect of manures containing carbon, it would have been seen, as we have frequently pointed out, that such a supply yielded a more characteristic result with the roots than with the other crops enumerated; next in order to these would probably come the leguminous crops; and lastly the cereals, which are benefited least of all by manures supplying carbon.

A study of this condensed summary of a vast collection of facts will be found highly instructive. As a main result it may be stated, that the average increase by mineral constituents alone is with the cereals less than 200 lbs., whilst with the leguminous crops, even though including so many cases of really deficient crop arising from disease, it is four times as much. On the other hand, the *cereal grains* give an average of from 1800 to 2000 lbs. of increase with nitrogenous manure alone; whilst by the same manure there was on the average, with the leguminous crops, not any increase at all. Then again, with turnips, we have by mineral manures alone, an average increase of gross produce of about 6¼ tons, but with ammonia-salts alone, of only as many hundredweights. But, if we still more carefully compare the action of the several individual constituents of manure, with

of their several combinations, upon each of the different
s, and then again crop with crop, we cannot fail to see, that the
ral result is entirely inconsistent with that which the collec-
analysis either of the crops or of their ashes would have led
, had this alone been our guide. Finally, in prominent
ne, the result is seen to be, that for the production of
ased growth, *nitrogenous manures* had the *most characteristic*
upon the *cereals; potass* on the *leguminous crops;* and
hates on *turnips.*

here is another very important point connected with
ring, in relation to which we must here adduce some
rimental evidence, and a few observations. The subject,
ver, is one which, both from its extent and importance,
nds that a separate paper should be devoted to its elucida-
; we therefore the less regret the very cursory manner in
h we are now obliged to notice it.

ne point to which we refer, is the constantly observed fact
ghout our experiments, that, although an increased produc-
of the cereal grains (the main saleable produce, and, as it
, the final product to which all farming operations tend) is
attainable in agriculturally adequate amount, by the accu-
tion of available nitrogen *within the soil itself*,—yet, in no
have we recovered in the increase of crop obtained, as much
gen as was supplied to the soil in manure. Now, if it be
ed, that increase of the *cereal grains* in agricultural quantity,
sentially connected with the supply to the soil of much more
gen than is recoverable in the increased produce obtained,
ill be obvious, that we have here a fact, which must funda-
tally affect the views we entertain as to the principles in-
ed, not only in direct manuring, but in those other main
ures of agricultural practice, which are had recourse to with
same result.

n relation to this subject, we have in our various papers, pro-
ently called attention to several of the main facts which our
eriments have brought to light. Thus, we have shown that,
r supplying to the soil twice or thrice as much nitrogen as
obtained in the increase yielded, there was in the succeeding
r, either no increase whatever due to the nitrogen not recovered
he year of its application, or that such increase in the second
r, if any, was not only extremely small, but that it occurred
y when the application of the previous year, had been obviously
y excessive in relation to the climatic or other circumstances
growth of the particular season. We have also called especial
ntion to the fact, that the increase produced by a given
ount of nitrogenous supply is very variable, according to the

variations of season, and of other coincident conditions of t
growth and maturation of the crop.

But, Baron Liebig in his criticisms equally ignores our fact
our observations, and our conclusions regarding them! With
view of maintaining that the increase of produce obtained wa
not proportional to the supply of ammonia by manure, and con
sequently that the results of our own experiments demonstrated
the contrary of that which he alleges we have concluded from
them, Baron Liebig compares the increase by a given amount of
ammonia in *different seasons*, without any reference either to the
varying character of those seasons, or to the fact, that in recording
the experiments of which he treats, *we had ourselves called
particular attention both to the actual variations, and to their influence upon the results in question.* Thus he selects for his purpose,
results obtained in the several seasons of 1844, 1845, and 1846;
and shows that in the last (1846), the increase obtained from a
given amount of ammonia-salts in manure, was once and a half
or twice as great as in the other cases. In reference to this
very point we had said:—

"It should be remembered, however, that as the season of 1846 was more
than usually favourable to the production of corn, any calculations founded
upon the results of that year *might lead to an over-estimate of what the am-
monia would produce in an average of years.*"—*Jour. Roy. Agr. Soc. Eng.*
vol. viii. part i. p. 247.

Again, speaking of the total amount of ammoniacal sa
added to one of our plots (10*a*), in six years, he says:—

"But as the whole 1960 lbs. was not added in one year, but in portio
during six years, the soil became each year richer in them than it was in t
preceding. There remained a residue from the previous year, which w
annually increased by the portion newly added."—*Principles*, p. 95.

He then, in direct contradiction to the evidence of our expe
ments, goes on to deduct from the amount of nitrogen suppl
to the soil in each year, that amount which he supposes was c
tained in the increase of crop obtained by it; he assumes t
the remainder accumulates from year to year, as a residue in
soil, the amount of which residue, taken together with tha
the salt newly added, is to be considered as the amoun
ammonia-salts yielding the increase of any particular year.
this way, by bringing forward from year to year an ass
efficient residue, which our experiments prove did not exi
calculates the increase of produce in the sixth year as d
1592 lbs. of ammonia-salts!—though 400 lbs. only wa
amount added as manure in that year. In this way it
arrives at the conclusion, that the produce for a given amo
nitrogen *steadily diminished!* He says:—

"*But it is and remains undeniably certain*, that the proportion of a

cal salts in the soil, whatever might be its exact value, must have increased from year to year, because ammoniacal salts (sulphate of ammonia and sal-ammoniac) are not volatile, and, *consequently, the unconsumed portion, or excess, must have remained in the soil. This being assumed as a fact which cannot be disputed,* these numbers establish the truth, already demonstrated by the earlier experiments, that the produce did *not increase in proportion to the increased proportion of nitrogen present in the soil;* but that, with the exception of the year 1848, the produce for the same amount of nitrogen *steadily diminished.*"—*Principles*, p. 97.

It is after the wholesale ignoring of our recorded facts, statements, and conclusions, which these quotations imply, and after such reasoning upon the pure assumptions taken in their stead as we have pointed out above, that Baron Liebig, using the word "*proportional*" in the exact numerical sense (which he well knows is entirely inconsistent with all our evidence and reasonings on this question), sums up his criticism by saying :—

"Mr. Lawes has disproved *what he intended to prove*, namely, that the excess of produce in this case *is proportional to the quantity of ammonia present in the soil*;—that is, *he has proved that a single, double, or treble supply of ammonia does not give a single, double, or treble excess of produce;* but that this excess is a constant quantity."—*Principles*, p. 135.

Already, however, in Germany, America, and this country, Baron Liebig's treatment of this question has been prominently commented upon. And thus it is, that he has been obliged to recur to the facts and conclusions involved in this part of the subject. At the recent meeting of the British Association at Glasgow he undertook to deal with this question ; and as the line of argument he then adopted was substantially that which he had already published in Germany in reply to the admirable strictures on his 'Principles' by Professor Wolff,* we shall, for convenience, refer to the translation of his own reply, made and published at his own (Baron Liebig's) request in America.†

In discussing this question, we need not for a moment entertain as an objection against observed collateral facts, Baron Liebig's argument, that if there be a loss of nitrogen in the growth of *increased* produce, there must necessarily be the same relation between the normal supplies of nitrogen and the amount assimilated under their influence on our unmanured plot. It must then be distinctly borne in mind, that it is of actually observed facts, in relation not to the growth of produce alone, but of an *increased amount* of produce by means of an accumulation of nitrogen within the soil, that we have now more particularly to speak. We may, however, say in passing, that we have frequently called attention to facts regarding the amount of constituents harvested over a given area of unmanured or equally manured

* Zeitschrift für Deutsche Landwirthe, 4en Heft.

† The Country Gentleman. Albany, N.Y., October 11, 1855, *et seq.*

land, in the cereals and leguminous crops respectively, v
calculated to give at least a direction to our conclusions,
ence to the assimilation of nitrogen in the case of an un
cereal plot. Thus, the striking fact appears, that unde
unmanured or mineral-manured conditions, the produce
gen per acre, may be twice and a half or thrice as gre
and the same season, with the leguminous, as with the ce
This relation, therefore, between the amount of nitroge
lated under given circumstances in the leguminous cro
pared with the cereal, is strikingly similar to that whic
between the nitrogen of manure and that in the *increase*
of the cereal obtained by its use.

Baron Liebig further alleges against our conclusions
have no evidence that the unrecovered nitrogen did n
in the soil for the use of the future crops; that we sh
employed very much smaller amounts of ammonia-salts
that the smaller did not give an equal increase of pro
the larger, as well as to ascertain the minimum amoun
monia-salts required to produce a maximum effect; and
that the assumption that 5 lbs. of ammonia is required t
a bushel of increase is no expression of a natural relation
manure and crops. We shall examine these several al

Firstly, then, as to the assertion that we have no evid
the unrecovered nitrogen of the manure did not rema
soil for the succeeding crops. Not only had *we* suffi
dence on this point, but Baron Liebig had himself, in
recorded results, the proof of it in the degree in which
ourselves maintained it. What we say is, that even when a
salts are not used in greater excess than is adapted
average effect in any given season, still, probably, only
third to one-half of the nitrogen so supplied, will be rec
the increase obtained in the year of the application;
unrecovered nitrogen will yield little or no increase in
ceeding year; that if, under these circumstances, am
again added, we shall, other conditions being equal, ag
large increase of produce; and further, that if more
have been employed than is suited to give a fair increa

experience of practical farming in the use of guano, and other nitrogenous manures, for the increased production of the cereal grains.

TABLE V.—Showing the influence upon the Wheat Crop, in the second season, of Nitrogen supplied in Manure (but not recovered in increase) in the preceding season.

Plots.	Seasons.	Ammonia-salts employed.	With or without Minerals.	Increase of Total Produce (Corn and Straw per acre).
		lbs.		lbs.
10*a*.	1845	336	none	2,093
	1846	224	none	1,374
10*b*.	1845	336	none	2,093
	1846	none	none	49 (less)
8*b*.	1847	400	minerals	2,715
	1848	none	do.	82
5*a*.	1851	600	minerals	3,477
	1852	none	do.	468
5*b*.	1851	600	minerals	3,778
	1852	none	do.	624

Secondly, Baron Liebig says—

"If it had accidentally occurred to Mr. Lawes to manure his field with 4, 5, or 6 cwt. of ammonia-salts, instead of with 3¼ cwt., and if in those cases the yield was *not increased* (*as we may with certainty assume would happen*), then he might with the same justice assert that the loss of ammonia is 6, 8, or 10 lbs. for every bushel of increased yield.

"Or if Mr. Lawes had applied ammonia-salts at the rate of 2 or 1 cwt., instead of 3¼ cwt. the acre, and then, after previous manuring with dissolved bones and silicate of potash, (whose action he has not taken at all into account), had harvested the same increase of 8 bushels; his conclusion that the soil suffers a loss of ammonia, would doubtless have been vastly modified. He has made the loss and not found it."—*The Country Gentleman*, Nov. 1, 1855.

And again—

"It never seems to have occurred to Mr. Lawes to determine the minimum of ammonia which was effective upon his field in producing maximum crops."—*Ibid.*

Doubtless it will be highly satisfactory to Baron Liebig to learn, that it *has* occurred to us to supply almost identically all the cases here demanded. Thus, instead of using only 400 lbs. of ammonia-salts, which is rather more than on the average of seasons is adapted to our soil, we have, over a series of years, employed 600 lbs. and 800 lbs. of these salts; and the result has been *exactly the reverse* of what Baron Liebig says "*we may with certainty assume would happen.*" That is to say,

the crop in those cases *was very considerably increased.* Though, as might be expected, in a diminishing numerical proportion to the excessive amount of ammonia now added. Then again, we have used, through the same series of years, respectively 200 lbs. and 100 lbs. of ammonia-salts, with, in each case, a full supply of soluble phosphates and alkalies; so that we have here again supplied the exact conditions demanded; and also the means of determining the "minimum" amount of ammonia which was effective in producing a maximum crop. Here, too, the results are precisely contrary to those which Baron Liebig has supposed they would be, and on the assumption of which he says, that *then* "his conclusions that the soil suffers a loss of ammonia would doubtless have been vastly modified. He has made the loss, and not found it."!

The following is a summary statement of the results obtained by the use of these gradationary amounts of ammonia, over a period in each case of three years, namely, 1852–4 inclusive. And in order to show by the side of these results, about what amount of produce was obtained on the same soil by means which the practical farmer will be better able to judge of, we also give the average produce by farm-yard manure during the same seasons; and, by the comparison here afforded, it will be seen, that some of the supplied amounts of ammonia were very far in excess of what was required to give a produce equal to that by the annual supply of farm-yard manure.

TABLE VI.—Showing the effects upon the Wheat Crop of gradationary amounts of Ammonia in Manure.

	Total Increase per acre (Corn and Straw).
	lbs.
Average of 3 years with minerals and 100 lbs. ammonia-salts.	760
Do. do. do. 200 do.	1,575
Do. do. do. 400 do.	2,915
Do. do. do. 600 do.	3,641
Do. do. do. 800 do.	4,555
Do. do. farm-yard manure	3,022

Here it is seen that the 100 lbs., the 200 lbs., and the 400 lbs. of ammonia-salts, gave a gross increase of produce (corn and straw together), almost identically proportionate to the amount of ammonia in the manure. As we have already said, however, the largest of these amounts (400 lbs.) is somewhat more than on the average of seasons will yield the most favourable result; and if it be much exceeded, the proportion of straw

to corn in the gross produce obtained will be much increased. It should be further added, too, as some qualification of the exact figures of the Table, that since the three seasons over which our average extends, include one at least which was unusually favourable to the production of corn, the result by even the 400 lbs. of ammonia-salts, as here recorded, will be rather better than would be obtained over a more extended period of time. There was, however, a still further increase of produce when more ammonia was employed; though, as already stated, the ratio of increase diminished the more rapidly the greater the *excess* of ammonia added in the manure.

Upon the whole, then, the result strikingly stands out, that we obtained a considerably greater amount of produce by the use of *much larger* amounts of ammonia than those which Baron Liebig has pronounced to be *excessive*, and to the use of which he attributes the conclusion which he assumes to be so erroneous. It is further strikingly obvious, that there was a very general uniformity in the proportion of increase obtained for a given amount of ammonia supplied, whether 400, 200, or 100 lbs. of its salts were added to the soil. Hence it follows, that if there were a loss of nitrogen when 400 lbs. of ammonia-salts were used, there must have been very nearly a proportionate amount of loss when the *minimum* quantity was employed; and consequently that the loss observed when the 400 lbs. was used could *not* be due simply to the supply of more nitrogen than was necessary for a *maximum* of produce, as maintained by Baron Liebig. In fact, *we have found the loss, and not made it!*

Again, Baron Liebig says:—

"The number 5, for the amount of ammonia, and the quantity 1 bushel for the increased yield, are not expressions for a natural relation between manure and crops. The first does not express the weight of ammonia necessary to produce a maximum of increase, equal to one, and ascertained by a series of observations, but is a mere stroke of fancy."—*The Country Gentleman.*

We will first show, by quotation from our papers, whether we have assumed "the number 5 for the amount of ammonia, and the quantity 1 bushel for the increased yield," as an *unconditional* and *undeviating* relation; or whether these numbers are not given simply as a practical average of our experiments, admitting deviations on either side, according to variations of season and other circumstances. Secondly, we will show whether or not that which we have assumed, is "ascertained by a series of observations," or whether it is "a mere stroke of fancy." In regard to the first of these points, we had said:—

"I am inclined to think that, for practical purposes, we may assume 5 lbs. of ammonia to be required for the production of every bushel of wheat beyond

the natural yield of the soil and season; at any rate, it will be useful to remember this as the amount until future experiments shall furnish further information on the subject."—*Jour. Roy. Ag. Soc. Eng.*, vol. viii., part i. p. 246.

"We may here observe that the production of straw, as well as that of grain, would seem to be intimately connected with the expenditure of nitrogen derived through the roots of the plant, and had we time to consider the question more fully on this occasion, we should not have dwelt so exclusively on the production of corn alone as we have done. We may, however, remark, that the production of a heavy crop of straw in a wet season is probably, from the cause alluded to, a very dearly purchased produce."—Vol. xii., part i. p. 27.

"In our paper upon the growth of wheat, published in the Journal of the Royal Agricultural Society in 1847, we have attempted an estimate of the probable amount of nitrogen required to obtain a given amount of it in the increased produce. We there provisionally assumed that 5 lbs. of ammonia were required to produce an increase of one bushel of corn and its equivalent of straw. We do not intend to enter fully into the question of the accuracy of this estimate on the present occasion, but we may observe in passing, that among the plots the history of which we have given in the foregoing pages down to the last harvest, there is not one, even under the best conditions as to artificial mineral supply, where the ammonia, on the average of seasons, has given an increase equal to that supposed in our estimate. . . . .

"Without further inquiring then, into the correctness of our estimate, it would seem that a loss of this kind during the growth of the plant is a fact which is sufficiently substantiated, at once by the practical experience of the farmer, and by experiments of an independent kind relating to it. And, let it once be recognised, in agricultural science, that there is a definite expenditure or consumption of the nitrogenous bodies derived through the roots, connected with the fixation and elaboration of certain constituents of plants, and that this is greater or less according to the sources or the exact composition or state of elaboration of the products, and an important step will be gained towards a clearer conception of the principles involved in the alternation in a course of cropping, of plants of varying products and habits of growth."—Vol. xii., part i. pp. 31, 32.

We will next show whether or not that which we have assumed regarding the excess of nitrogen required in manure over that obtained in the increase of the cereals grown by it, was "a mere stroke of fancy," or whether it was "ascertained by a series of observations." On this subject we will bring one quotation from our former papers, and we will then adduce a summary of an immense mass of experimental evidence on the point in question. We say:—

"Thus, among from *two to three hundred experiments* with ammoniacal manures, we have in no single instance recovered in the increase the amount of nitrogen provided in the manure; and this fact is perfectly consistent with the amounts of produce found, in the experience of the farmer, to be obtained by the use of Peruvian guano and other nitrogenous manures."—*Jour. Roy. Agr. Soc. Eng.*, vol. xii., part i. p. 29.

In the following Table (VII.) is given a summary of the amount of nitrogen recovered in the increased produce, for every hundred parts of it supplied in manure, in the cases both of barley and of wheat. It will be seen, that we have here the

results obtained under eight different conditions as regards the nature of the nitrogenous manure, its amount, or the circumstances under which it was employed, viz., whether with or without the addition of mineral manures. The number of cases brought under calculation, including both wheat and barley, amounts to nearly 300; and the number of years over which the experiments extended, was nine in the case of wheat, and three in the case of barley. The minor questions as to the influence of individual seasons, the varying proportions of corn and straw, the slightly varying percentage of nitrogen due to the combined influences of season and manure, and other points, it would, of course, be impossible to treat of, in the mere outline which we are now professing to give. With regard, however, to the varying percentage of nitrogen in the produce according to the amount of it in manure—a point to which Baron Liebig alludes—we may simply say, that it in no way materially affects the general result obtained. We may add, that the percentages of nitrogen in corn and straw respectively, employed in the calculations, are in most cases the results of direct determinations made upon mixed samples of the produce (grain and straw separately), of the several plots in each year, the average of which go to form a single result in the Table.

TABLE VII.

Summary—Nitrogen in total increase (Corn and Straw) for 100 in Manure.
CROPS—Wheat and Barley.

General Description of Manures.	Wheat.	Barley.
1. Ammonia-salts (standard amount) alone	31·9	43·4
2. Nitrate of soda (do. do.) alone	29·3	28·4
3. Ammonia-salts (do. do.) with minerals...	42 5	48·1
4. {Ammonia salts or rape-cake} (do. do.) do. ...	38·3	35·5
5. Ammonia-salts (less than standard) do. ...	53·4	60·6
6. Nitrate of soda (do. do.) alone	52·2	42·4
7. Ammonia-salts (more than standard) with minerals	34·3	...
8. {Ammonia-salts or rape-cake} (do. do.) do.	37·2	...
Means	39·9	43·1

The results here stated may surely be considered as "ascertained by a series of observations." We have, first, the amount of nitrogen recovered in the increase of wheat and barley, when what is termed a "standard amount" of nitrogen alone, is employed; that is to say, such an amount as experience shows will yield a pretty full, but rather too heavy a crop to bear the

average of seasons. We have this amount supplied both in the form of ammonia-salts, and in that of nitrate of soda. We have it also with the admixture of minerals; and again when, besides minerals, the same amount of nitrogen is supplied indifferently in the form of rape-cake alone, or a mixture of rape-cake and ammonia-salts. We have next, in Series 5 and 6, the amount of nitrogen recovered, when *less* than the standard amount of nitrogen was employed. And lastly Series 7 and 8, when *more* than the standard amount of nitrogen was used.

Now, since *season* has a very great effect upon the amount and description of the increase obtained by nitrogenous manures, and as the whole of these series do not apply equally to the same years, it is obvious that niceties of variation cannot be discussed upon such a summary statement of results as is here given. The general fact is clear, however, that the proportion of the supplied nitrogen not recovered in the increase of crop, is, in all cases, very large. The proportion of loss is greater when the standard amount of nitrogen is used alone, than when a liberal supply of minerals is also added. But it is seen, that even when only the standard amount of nitrogen is used (an amount which does not yield more increase than should be obtained under high farming on the land in question), and when to this is added a liberal supply of mineral constituents, still there is little more than 40 per cent. of the supplied nitrogen recovered in the increased produce of corn and straw which is obtained. When, again, with the minerals, *less* than the standard amount of ammonia is employed, that is, *less than is adequate to give an amount of crop equal to that produced by good farming*,—we have, even in that case—a case which of course *in practice could not be followed*—little more than 50 per cent. of the supplied nitrogen recovered in the increase of crop. But when, with the mineral constituents, we add *more* than the standard amount of nitrogen, *though not more than gave a still further increment of increase*, we have little more than one-third of the nitrogen of the manure returned in the increase.

It is seen, that with both wheat and barley, a large amount of nitrogen alone, applied as nitrate of soda, gives a worse result than a large amount of salts of ammonia alone. The nitrogen applied as *rape-cake* gave, in the case of wheat, nearly an equal result with that in ammonia-salts; when used with barley, it gave considerably less return in its increase than when applied in the latter form; but the amount of rape-cake employed, was obviously far too great for the favourable maturing of the barley in the average of seasons.

As a final average it is seen that we have, including all these cases and extending over so many years, in the case of *wheat*, only 39·9 per cent., and in that of barley only 43·1 per cent., of

the nitrogen of the manure recovered in the increase of crop!—and certainly the near approximation in the averages of the two crops is not a little striking; especially when we remember, that in the case of the barley there were no instances of *more* than standard amount of nitrogen used, which would obviously have brought down its final average nearer to that of the wheat.

Now, the final average here obtained in the case of *wheat*, would represent exactly 5¼ lbs. of ammonia for each bushel of grain (with its equivalent of straw), obtained by its use, assuming average proportions of corn to straw, and of nitrogen in both: and, again, by the same method of calculation, the return of rather more than 40 per cent. of nitrogen, the result where the standard amount of ammonia with minerals was used, would be almost identically equivalent to 5 lbs of ammonia in manure for every bushel of corn, and its equivalent of straw, obtained as increase of crop!

So much, then, for the indications of some hundreds of direct experiments on this subject. But we further unhesitatingly maintain, that the general result here arrived at, agrees very closely indeed with that of common experience in the use of guano and other nitrogenous manures for the increased growth of grain.

Consistently with the object of this paper, which is simply to meet the objections of Baron Liebig to our facts and conclusions, and to adduce, in the form of condensed summaries of our experiments, such evidence as shall serve to establish the facts and conclusions thus disputed, it would be out of place, even did our space permit it, to enter into any detailed consideration of what may be the scientific explanation of the practical loss of nitrogen, which *as a simple fact* we have just illustrated. Hoping, however, to recur to this subject before long, we may nevertheless, in passing, state, that various experimenters have recorded an evolution of nitrogen from the leaves of growing plants, beyond that which they thought they could attribute to the atmosphere with which their plants had been supplied; but as observations of this kind have not established a clear distinction between the leguminous and the cereal plants of our rotations in this respect, further evidence is of course necessary, before we should be justified in confidently attributing the phenomenon in question, to the functional actions which have been supposed to be the source of the evolution of nitrogen from the leaves of plants, observed in the experiments alluded to. The only explanation of this practically observed loss, which has been suggested as *special to the cereals*, is that proposed by Mr. Way; namely, that the silica required by these plants, is taken up as a silicate, of which ammonia is a base; and that this alkali, or its constituents, is evolved upon the fixation of the silica by the plant. Professor

Wolff has to a great extent adopted this view; and has adduced various circumstances connected with the development of these plants, as corroborative of its probability. Baron Liebig has, on the other hand, energetically repudiated the explanation offered by Mr. Way; founding his objections on the fact, that water containing ammonia or its salts dissolves less of the alkaline silicates than does pure water itself. Experiments of this kind, made upon chemical compounds *out of the soil*, cannot be considered satisfactory as the ground of conclusions as to what would happen under the complicated conditions of cultivated soils. We have, however, found, that water containing salts of ammonia dissolved less silica than pure water, when percolated through a given bulk of soil. But the question may, after all, not so much depend upon the *amount* of the silica which will be dissolved in the soil, as upon the state of chemical combination from which it is most easily assimilated by the plant.

It has been partly with a view to aiding the solution of the question of the varying amount and sources of the nitrogen assimilated by the different plants of our rotations, that we have, for a series of years, conducted investigations on the amount of water passing through different plants, under equal and varied conditions of growth, in relation to the quantitative fixation in them of their several constituents. The results of these investigations, as we have elsewhere pointed out, have an interesting bearing upon the phenomena we have been discussing. But so important has it appeared to us, to clear up many open questions which suggest themselves, that not long ago we induced a promising and accomplished young chemist from the laboratory of Professor Bunsen (Dr. August Pauli), to devote himself for two years to this subject, in the laboratory at Rothamsted. Unfortunately, his death, almost as soon as he had commenced his labours, prevented the further prosecution of the exact path of research then proposed; though we still hope that investigations which we have for some time had in progress, and to which we shall now direct more close attention, will enable us to record before long, further advance in our inquiry.

But there are means adopted by the farmer of increasing the growth of grain, without either the artificial supply of nitrogen to the soil, or the intervention of a fallow *crop*. These are, *bare fallow* and the *mechanical operations of the farm*. Now, as Baron Liebig has modified his views on the efficiency of these means, in his "Principles" just published, we must take the statement of his views as given in the third and fourth editions of his main work, to show what, until lately, he advocated on this question. In these editions he gave a distinct and separate

llow and the mechanical operations of the farm, in
id all but the first of the following sentences; this
ely preceding that special chapter:—

receding part of this chapter it will be seen that fallow is that
e when the land is exposed to progressive disintegration by
e weather, *for the purpose of liberating a certain quantity of*
ca to be absorbed by future plants.
l and frequent working of fallow-land will accelerate and
ntegration: for the purposes of culture it is quite the same
nd be covered with weeds, or with a plant which *does not*
sh from the soil."—*4th Edition*, p. 127.

of the mechanical operations of the farm, he says:—

n consists in accelerating the weathering or disintegration of
us offers to a new generation of plants their necessary mineral
a form fit for reception."—*4th Edition*, p. 130, 131.
the surface of the soil and endeavour to make every particle
to the action of *carbonic acid and oxygen.* Thus we procure a
of *soluble mineral substances* which are indispensable for the
id luxuriance of a new generation of plants."—*4th Edition*,

:—

its most extended sense, means that period of culture during
exposed to the action of the weather, for the purpose of en-
rtain soluble ingredients. In a more confined sense, the time
be limited to the intervals in the cultivation of cereal plants;
of soluble silicates and of alkalies is an essential condition to
f such plants."—*4th Edition*, p. 132, 133.
nical operations of the farm, fallow, the application of lime,
g of clay, unite in elucidating the same scientific principle.
eans of accelerating the disintegration of the alkaline silicates
d of supplying to plants their necessary constituents at the
of a new vegetation."—*4th Edition*, p. 136.

ow would generally be applicable to land after its
exhaustion by the growth of a series of crops, and as
n for the growth of a succeeding crop of grain—and
, that in 99 out of 100 such cases, in ordinary culti-
mineral manures would not adequately raise the pro-
the application of ammonia salts or nitrate of soda
nly do so;—we cannot imagine, therefore, that the in-
oduce in such a soil *by fallow*, can be measurable by
of mineral constituents liberated by the chemical
e atmosphere on the soil. We fully grant, indeed,
tion—such liberation of mineral constituents—does
uring fallow; but we maintain, that there would be
increase of produce, unless at the same time there
lensation of available nitrogen from atmospheric
in the soil itself, and that it is by the amount of this
n of available atmospheric food of plants *within the soil*,
by the amount of liberated soil-proper constituents,
reased produce of grain will be measurable.

It should be mentioned, that in the fourth and last edition of Baron Liebig's main work, in the chapter entirely devoted to an explanation of the beneficial effects of fallow and the mechanical operations of the farm, he does not say one single word in reference to the accumulation by these means, of available atmospheric food—nitrogen—within the soil itself; but only of the greater supplies of the *mineral* or soil-proper constituents, which are thereby rendered soluble and available for the plants. We have, on more than one occasion, called attention to the former influences; and also to the fact, that a study of the properties of soils in relation to the accumulation of the atmospheric food of plants, promised to be of more value to agriculture, than that of the mere determination of their percentage composition in the *mineral food* of plants; and, to the opinion that this is a field of inquiry highly deserving of the attention of the agricultural chemist, we are happy to have *now* the sanction of Baron Liebig himself. Thus he *now* says:—

"*Fallow* is the time during which this weathering takes place. During fallow, carbonic acid and *ammonia* are conveyed to the soil by the rain and the air; the *ammonia* remains in the soil, if substances be present in due proportion which deprive it of its volatility by combining with it."—*Principles*, p. 26, prop. 26.

And again:—

"But so to prepare the *soil* as to enable *it* to extract from the air, and the other sources offered to plants by nature, and to condense in its products a *maximum of nitrogen*,—this, indeed, is a problem worthy of scientific agriculture."!—*Principles*, p. 105.

Here again, then, in his 26th, as well as in his 14th proposition, there is evidence that Baron Liebig's views have been strikingly "corrected and enlarged"! This influence of *fallow* is then we say, not that, there being within the soil a more liberal provision of the mineral food of plants, they, *the plants*, are enabled to absorb more nitrogen from atmospheric sources: but it is, so far as accumulation of nitrogen is concerned, that *the soil itself* has absorbed it from atmospheric sources; without which condensation within the soil, of the atmospheric food of plants, no adequate increase of produce of grain would have been obtained, however great might have been the increased supply of the *soil-proper* or *mineral* food of the plants.

We shall presently endeavour to trace the chemical statistics of an actual *rotation of crops itself*, which will enable us to form a judgment, whether the facts which are thus elicited, taken in connection with those which have been indicated with regard to the action of manures on the individual crops, do not afford us some insight into the chemical principles upon which that main arm of agriculture, *rotation*, is founded. Before, however, enter-

upon a consideration of our own evidence and conclusions on
point, it may be well to give a very rapid review, of what
be called the *natural history* of the various opinions which
of late years been entertained, regarding the two most im-
ant and closely allied subjects, of *manure* and *rotation*.
t the time of the appearance of Baron Liebig's first work in
O, the prevailing impression, which had received much con-
ation from the investigations of M. Boussingault, was, that
ogen was one of the most important constituents of manure.
on Liebig, in his first edition, also dwelt particularly on this
it; but at the same time, he drew much more special attention
he importance of the *mineral* constituents of plants than had
erto been bestowed upon them. After the publication of
on Liebig's first book, M. Boussingault published much more
y the results of his various agricultural investigations, and
conclusions to which he had arrived in regard to them.
With respect to *manures*, he (M. Boussingault) concluded that
ir relative value was determinable, more by the amount of
ogen they contained, than by that of any other constituent.
d in reference to the subject of *rotation*, after having given
chemical statistics of three separate courses, in which roots,
minous crops, and cereals had been alternated with each
er, and also of one with wheat grown two years in succession,
r fallow and manure, he thus speaks in regard to the mutual
tions of different crops:—

In the five years' rotation, it may be observed that there are two crops, hoed crop and the forage crop, which yield substances to the ground that both abundant in quantity and rich in azotised matter, and it is unstionable that these crops act favourably on the cereals which succeed n. But data are wanting for the appreciation of their specific utility to general rotation."—*Rural Economy*, p. 488.

And, again, in the next page, he says:—

When the relative value of different systems of rotation are discussed in way we have done, we in fact estimate the value of the elementary matter ved from the atmosphere by an aggregate of crops; but the procedure erally followed is silent when the question is to assign to each crop in icular the special share which it has had in the total profit."

Now, Baron Liebig, after detailing the experiments of M. ssingault—in the course of which he argues, that inasmuch a larger amount of nitrogen was obtained in some of the later ps of the rotation, than in the earlier ones which immediately ceeded the application of the manure, it was obvious, that nitrogen of the crops could not be due to the nitrogen of the nure which had been applied—says:—

Boussingault concludes that leguminous plants *alone* possess the power of propriating, as food, nitrogen from the air, and that other cultivated plants not *at all* possess this property. Hence the great importance which Bous-

singault ascribes to manures containing nitrogen, for, according to his view, the commercial value of a manure depends on its amount of nitrogen. *But all these conclusions are thoroughly erroneous; for, if they were not so, it must follow that potass, lime, and silica plants, unless they belonged to the leguminosæ, would not produce any nitrogen, unless they were supplied with manure containing that element.*"—*4th Edition*, p. 207, 208.

Baron Liebig goes on to maintain, that, owing to the method of experimenting adopted by M. Boussingault, he had obviously under-estimated the amount of nitrogen which he had supplied in the manure at the commencement of his rotations; and that, in point of fact, he had added much more of that constituent to the soil, than he had taken off in his course of crops. And, on this point, he says:—

"Hence his erroneous conclusion, that the leguminosæ alone possess the power of condensing nitrogen from the air; and that it is necessary to furnish nitrogen to the gramineæ, and to plants such as turnips and potatoes."—*4th Edition*, p. 208, 209.

Baron Liebig supports his general argument by reference to the produce of Hungary, Sicily, the vicinity of Naples, the valley of the Nile, the meadows of Holland, and of other localities; and he maintains, that the nitrogen in these cases must have been derived from the atmosphere, and not from manure. And, he asks:—

"Are the fields of Virginia, the fields of Hungary, our own cultivated plants, not able to receive it from the same sources as the wild-growing vegetation? *Is the supply of nitrogen in animal excrements a matter of absolute indifference;* OR DO WE OBTAIN IN OUR FIELDS A QUANTITY OF THE CONSTITUENTS OF THE BLOOD, ACTUALLY CORRESPONDING TO THE SUPPLY OF AMMONIA?

"*These questions are completely solved by the investigations of M. Boussingault; which are so much the more valuable, as they were instituted with a totally distinct object in view.*"—*4th Edition*, p. 205.

We could point out other sources of error in the reasoning of Baron Liebig, but we will here simply call attention to the fact, that in the amount of nitrogen (22 lbs. per acre), which he says the fields of Virginia annually yield without manure, we have the most satisfactory proof of the inapplicability of any deduction from such an instance, regarding the requirements of *our own cultivated plants*. Thus, an average crop of wheat in this country, under good cultivation, will contain twice as much nitrogen as is here supposed.

It is in reference to the facts and arguments above alluded to, that Baron Liebig concludes as follows, in the sentence which, with reference to special points, we have quoted already more than once:—

"Hence it is quite certain, that in our fields, the amount of nitrogen in the crops is *not at all in proportion to the quantity supplied in the manure*, and that the soil cannot be exhausted by the exportation of products containing nitrogen (unless these products contain at the same time a large amount of mineral

ingredients), *because the nitrogen of vegetation is furnished by the atmosphere, and not by the soil.* Hence also we cannot augment the fertility of our fields, or their powers of production, by supplying them with manures rich in nitrogen, or with ammoniacal salts alone. *The crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure.*"—*4th Edition*, p. 210.

From this short recital, the reader will be able to form a judgment, of what were the prevailing ideas, and what the points of question *regarding manure*, and therefore what was the extent of the meaning of Baron Liebig, when he wrote the sentences quoted above, and considered it so essential to attribute a *preponderating value and importance* to the *mineral* constituents of manure. And it was in reference to the conclusions arrived at by the facts and arguments above referred to, taken in connection with a consideration of the sources and mineral composition of animal excrements, that Baron Liebig in the preface to the 3rd and 4th editions of his main work (published respectively in 1843 and 1847), said:—

"And I am now, for the first time since the completion of these labours, in a situation to give a simple and determinate expression to my view of the origin of animal excrements, and of the cause of their beneficial effects on the growth of all vegetables."

To vindicate himself, however, from the imputation now made by most writers on the subject, that in these arguments and conclusions he has underrated the value and importance of nitrogen or ammonia within the soil, Baron Liebig quotes in his "*Principles*," recently published, the following sentence, occurring in the same chapter of his work as that from which we have made the extracts given above.

"In order to obviate any misunderstanding, we must again draw attention to the fact, that this explanation is not in any way contradicted by the effects produced on the application of artificial ammonia, or of its salts. Ammonia is, and will continue to be, the source of all the nitrogen of plants; its supply is never injurious; on the contrary, it is always useful, and, for certain purposes, indispensable."—*4th Edition*, p. 212.

This vindicatory sentence, quoted from his previous work, Baron Liebig now adduces with the following preface:—

"In order not to excite new doubts, and in order *to put an end to a misunderstanding, which I thought, but vainly, as it appears, I had rendered impossible in my work, I repeat here what I said in that work.*"—*Principles*, p. 107.

It would have been more candid if Baron Liebig had given the paragraph in question to the end; for, in what immediately succeeds to the sentences which he here brings forward, is contained the clearest proof that there has been no misunderstanding such as he here complains of.* The continuation in his work is as follows:—

* Mr. Maskelyne also, in the 'Saturday Review' of December 15, gives the

"But, at the same time, it is of great importance for agriculture, to kno[w] with certainty that the supply of ammonia is unnecessary for most of o[ur] cultivated plants, and *that it may be even superfluous, if only the soil conta[ins] a sufficient supply of the mineral food of plants, when the ammonia requi[red] for their development will be furnished by the atmosphere. It is also [of] importance to know, that the rule usually adopted in France and in Germa[ny] of estimating the value of a manure according to the amount of its nitroge[n], is quite fallacious, and that its value does not stand in proportion to [its] nitrogen.*"!

Such, then, were the reasonings and conclusions of Bar[on] Liebig regarding the relative value of the constituents of *manu[re]*, founded, to a great extent, upon a consideration of the exper[i]ments of M. Boussingault on the chemical statistics of *rotati[on]*, and in opposition to the opinions arrived at by the latter [in] regard to those experiments. On the chemical principles involv[ed] in *rotation itself* Baron Liebig thus expresses himself:—

"In a more confined sense, the time of fallow may be limited to the interv[al] in the cultivation of cereal plants; for a magazine of soluble silicates and alkalies is an essential condition to the existence of such plants. The cultiv[a]tion of potatoes or of turnips during the interval will not impair the fertil[ity] of the field for the cereals which are to succeed (supposing the supply of alkalies to be sufficient for both), because the former plants do not require any of the silica necessary for the latter."—*4th Edition*, p. 133.

Again, after many pages of illustration of the importance of the *mineral*, or *soil-proper* constituents, he says:—

"It follows, then, from the preceding observations, that the advantage of the alternate system of husbandry consists in the fact that the cultivat[ed] plants abstract from the soil unequal quantities of certain nutritious matte[rs].

"A fertile soil must contain in sufficient quantity, and in a form adapt[ed] for assimilation, all the inorganic materials indispensable for the growth of plants.

"A field artificially prepared for culture, contains a certain amount of the[se] ingredients, and also of ammoniacal salts and decaying vegetable matter. T[he] system of rotation adopted on such a field is, that a potash-plant (turnips or potatoes) is succeeded by a silica-plant, and the latter is followed by a li[me]-plant."—*4th Edition*, p. 169.

And in his "Principles," recently published, he sums up t[he] rationale of rotation in his 35th Proposition, thus:—

"On the unequal quantity and quality (solubility, &c.) of the mine[ral] constituents, and on the unequal proportions in which they are required for the development of the different cultivated crops, depends the *rotation of crops*, and the varieties of rotation employed in different localities."—P. 2[90].

Here, then, we have distinctly enough set forth, even up to the present time, Baron Liebig's *mineral theory* of rotation; a[nd] we have already seen, that he has pronounced as "thoroughly erroneous," M. Boussingault's conclusions as to the greater dependence of the cereals grown in our rotations, upon nitrogen

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sentence *without the continuation*, to illustrate our unfairness in not f[ully] quoting Baron Liebig!

vided in the soil, and as to the greater reliance of the minous crops grown in alternation with them, upon atmoeric sources of nitrogen;—and also his conclusion that the unt of produce in the rotation is in proportion to the ogen in the manure.

Now, if M. Boussingault really did intend to say, "that leguminous plants *alone* possess the power of appropriating, as food, ogen from the air, and that other cultivated plants do not at possess this property," he certainly here committed an error; t is to say, if his meaning were, that the latter would assimi- only the amount of nitrogen conveyed to the soil *in the form manure*, and that they would not give a certain annual average duce independently of such supply. Such an error, if it e committed, would easily arise from the fact, that in his own eriments on the growth of wheat by means of manure, in ich he only recovered in the produce about as much nitrogen as manure contained, he had not by the side of his manured plot growing the same crop without manure. By such a colral experiment, he would have learned how much of his total duce was due to soil and season, independently of direct nure, and how much to the latter. Had he, indeed, possessed se data, he must then have concluded, that the cereals did umulate a limited amount of nitrogen from natural sources; l that the *increase* beyond this amount, was obtained only at st of much more nitrogen in the manure than was stored up the *increase* of crop produced by it. And had M. Boussinlt clearly appreciated this fact, regarding which, since the e he wrote, so much evidence has been recorded, he would rcely, whilst so prominently calling attention to the distinctions ich he observed in regard to the requirements of the cereals l leguminous plants in his rotations, nevertheless, have said, eference to those admirable results, that they rather afforded iew of the circumstances of an entire rotation, than threw any it on the special share in rotation of the individual crops. could he have failed to see, that in those distinctions which really did point out, was the very key to the chemical prines involved in rotation of crops. M. Boussingault, indeed, inctly called attention to the fact, that the benefits derived n growing a leguminous crop before a cereal, must to a great ent arise from the amount of organic matter thus accumulated hin the soil as a manure for the latter. He further pointed , that the very restorative leguminous crops, nevertheless e from the soil a very large proportion of some of the most ortant of the mineral constituents; and from the latter fact seems to have drawn the inference that in the choice of our cession of crops, care should be taken to make the selection

with clear reference to the amount of the various mineral constituents removed from the land in the different crops. Was there not, however, we may ask, in the very facts here recorded, namely that notwithstanding the exhaustion of minerals the clover was still so good a preparative for wheat—was there not in these coincident facts, that which would rather lead us to suppose, that the benefits arising from the order of succession merely of restorative and other crops, was little dependent on the mineral requirements of the individual crops?—and in fact, that if on the restorative crop, with its large demand for minerals, we enabled to grow luxuriantly, we might then conclude, that the soil was so rich in available mineral constituents, that the succeeding crop with its comparatively meagre demand, and which the former is known to be so subservient by the matter it leaves behind it, was little likely to find them wanting?

Baron Liebig, however, carries the mineral explanation of tation very much further, when he says, in regard to M. Boussingault's opinions:—

> "But all these conclusions are thoroughly erroneous; *for, if they were so, it must follow that potass, lime, and silica plants, unless they belonged the leguminosæ*, would not produce any nitrogen, unless they were supplied with manure containing that element."—*4th Edition*, p. 208.

Nor could Baron Liebig have reasoned as he did in regard to the analysis of M. Boussingault's rotations, had he, not only dwelt more upon the composition of each individual crop and their relations to each other, but at the same time recognised that which he will not even now admit, namely, that any *increased produce* of wheat is obtained only at the cost of more nitrogen provided in the manure than is recovered in that *increased produce*.

But let us see how *the mineral theory of rotation*, as expressed in Baron Liebig's 35th Proposition, is consistent with the evidence of direct experiment.

In Table VIII. we have the chemical statistics of three actual rotations; in each of which the course consisted of Swedish turnips, barley, clover, and wheat; and in all cases the entire produce of the swedes (both leaf and root) was removed from the land.

In rotation 1, the course commenced without any manure at all.

In rotation 2, it commenced with a manure of superphosphate of lime alone.

And in rotation 3, with a liberal mixed manure, containing rape-cake, ammonia-salts, potash, soda, and magnesia, and superphosphate of lime.

The constituents per acre which are calculated are—dry organic matter, nitrogen, total mineral matter, and the phosphoric acid,

tash, lime, magnesia, and silica contained in the latter. Th
y organic matter, nitrogen, and mineral matter, are in most
ses calculated from direct determinations, made on the produce
the different plots; but in any cases where such direct results
ere not attainable, the averages of allied cases have been taken.
he *constituents* of ash are, however, in all cases calculated from
a adopted average percentage, deduced from a consideration of
l recorded analyses with which we are acquainted,* taken in
nnexion with the analyses of similar ashes made in the labora-
ry at Rothamsted:—

ABLE VIII.—Chemical Statistics of three Rotations, constituents per acre (lbs.). Entire produce of Swedes (leaves and roots) carted off the land.

	1848. Swedes.	1849. Barley.	1850. Clover	1851. Wheat.
Rotation 1.—Swedes, unmanured.				
ry organic	2460·	3872·	4325·	4315·
itrogen	64·	52·	142·	57·
ineral	127·	179·	417·	217·
hosphoric acid	11·5	21·1	31·3	24·6
otash	33·8	31·3	83·5	33·4
ime	19·3	12·6	125·2	11·4
agnesia	3·3	7·2	35·5	7·2
ilica*	2·0	92·1	12·5	125·8
Rotation 2.—Swedes, by Superphosphate of Lime.				
y organic	3945·	2810·	4450·	4583·
trogen	98·	38·	146·	60·
neral	228·	129·	429·	238·
sphoric acid	20·7	16·0	32·2	26·7
ash	61·0	22·8	85·9	36·5
ne	34·4	8·8	128·8	12·4
gnesia	5·9	5·3	36·5	7·9
ca*	3·7	65·3	12·9	137·9
Rotation 3.—Swedes, by mixed Manures.				
organic	4984·	3269·	5164·	4520·
ogen	139·	45	170·	59·
ral	227·	145·	498·	234·
horic acid	19·9	17·8	37·4	25·6
h	58·3	25·6	99·7	35·6
... ...	36·9	10·0	149·5	12·2
sia	6·0	6·0	42·3	7·6
'	3·7	73 8	14·9	136·6

* In some cases *sand* is obviously included with the "silica."



much more—of phosphoric acid, potash, lime, and magnes
off the land in the clover crop, than in either the barley or t
And it should be remarked, that the produce of wheat
after the interposition and heavy mineral exhaustion of th
was in every case a very full one; in fact, it was such in
that we have every reason for concluding, that it was near
what would have been obtained had it been grown imm
succeeding the barley. The fact is, therefore, that w
very much larger produce of wheat after this great drain
land of phosphoric acid, potash, lime, and magnesia,
should have had without the intervention of the crop w
tracted them. But there is one mineral constituent,
silica, which was taken out in very small quantity by th
though in very large quantity both by the preceding ba
the succeeding wheat.

If, therefore, the benefit of the intervention of the cl
pended upon its exhausting less of certain mineral con
of the soil than the wheat which was to succeed it, it co
be in reference to *silica* that it had this beneficial action. B
Liebig has told us, that, provided there be a sufficiency
able alkali in the soil, there will never be a deficiency of
silica. And if this be so, since we find that in every case, t
found in the land nearly three times as much potash as was
by the succeeding heavy crop of wheat, we can hardly
the benefit of the clover upon the wheat crop to its cons
of soluble silica in the soil for the latter. But further,

Taking together, then, the now established facts, that the supply of available nitrogen to a cultivated soil, greatly increases the produce of wheat,—that the clover, which has the same effect, has rendered the soil much poorer in all the important mineral constituents required by the wheat, except silica,—and that the clover again is known to yield twice or three times as much nitrogen per acre as a cereal grain when equally provided with it by manure, and that it also leaves a large amount of organic residue in the land,—have we not in these facts, sufficient ground for concluding, that the beneficial effect of the leguminous clover has been the accumulation from atmospheric sources *within the soil itself, of available nitrogen for the increased growth of the cereal grain?* And have we not in this fact, taken in connection with that of the much larger amount of nitrogen required in manure than is obtained in an increased produce of wheat obtained by its use, the clearest key to the benefits of the so-called *fallow crops* in alternation with grain? Have we not in these facts the clearest proofs, that *the rotation of crops* does *not* depend "on the unequal quantity and quality (solubility, &c.) of the mineral constituents, and on the unequal proportions in which they are required for the development of the different cultivated crops?" And how, we would ask, if an adequate increased growth of corn be only attainable by the accumulation of *available nitrogen within the soil*—and if one of the chief means of the farmer to this end were a *rotation of crops*, by which he is enabled "to produce manure for his corn crops, that is, for the growth of his saleable produce"—and if the great object to be attained in our time is "to substitute for a rotation of *crops* a rotation of the proper *manures*"—how, we would ask, would an adequate increase of grain be possible under such circumstances, by the supply of a *rotation of manures from without*, founded on a knowledge of the composition of the ashes of the crop to be grown?

To resume—as the result of our whole inquiry we conclude:—

1. That the manure indicated by the resultant requirements of British agriculture has no *direct connexion* with the composition of the mineral substances collectively found in the ashes of the produce grown on, or exported from the farm; and that the direct mineral manures which *are* required, are not advantageously applied for the direct reproduction of the exported corn, but should be used for the green or *fallow crops*—one of whose offices it is, to collect from the atmosphere, or to conserve on the farm, *available nitrogen*, for the increased growth of the cereal grains.

2. That the nitrogen required to be provided *within the soil* for this purpose, is far greater than that contained in the increase of produce obtained by it.

3. That the chemical effects of *fallow*, in increasing the growth of the cereal grains, are not measurable by the amount of the additional mineral food of plants liberated thereby, these being, under ordinary cultivation, in excess of the assimilable nitrogen existing in or condensed within the soil in the same period of time. The amount of the latter therefore—*(i.e.)* the *available nitrogen*—is the measure of the increased produce of grain which will be obtained.

4. That the beneficial effects of *rotation*, in increasing the production of saleable produce (so far as they are chemical), are *not* explained by the fact of one plant taking from the soil more of the different mineral constituents than another, but depend on the property of the so-called green or *fallow* crops of bringing, or conserving, upon the farm, more substance rich in nitrogen than is yielded to them in manure; whilst the crops to which they are subservient, are both largely exported from the farm, and yield in their increase considerably less nitrogen than is given to them in manure.

5. In a word—that, in the existing condition of British agriculture, a full production of the *saleable cereal grains*, with other exportable produce, is only attainable, whether by *manures*, *fallow*, *or rotation*, provided there be an accumulation of available nitrogen *within the soil itself*.

Rothamsted, Herts, December, 1855.

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ON

THE GROWTH OF WHEAT

BY THE

LOIS WEEDON SYSTEM, ON THE ROTHAMSTED SOIL;

AND ON

THE COMBINED NITROGEN IN SOILS.

By J. B. LAWES, F.R.S., F.C.S.,

AND

Dr. J. H. GILBERT, F.C.S.

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VOL. XVII, PART II.

ON THE

LOIS WEEDON PLAN OF GROWING WHEAT;

AND

ON THE COMBINED NITROGEN IN SOILS.

In the year 1849, when wheat was selling at 5*s.* per bushel, and the "*Stout British Farmer*" was complaining of the badness of the times, and felt somewhat perplexed how to pay his rent and retain a little surplus, there appeared a pamphlet entitled '*A Word in Season*,' in which the author explained his method of growing wheat year after year without manure; and he promised to those who would adopt his system and follow his directions, a profit of 4*l.*, 5*l.*, or 6*l.* per acre. Of the numerous essays which have been published on agricultural subjects of late years, few have attracted more attention than this. Commencing its career in 1849 as a pamphlet of less than twenty pages, it has since gone through edition after edition, until now, in 1856, we find the subject much extended, and presented as a book of 120 pages.

In this little book, entitled '*Lois Weedon Husbandry*,' the author, the Rev. S. Smith, goes into considerable detail not before given, as to his mode of growing root and other green crops. But confining attention for the present to *wheat*, it may be observed, that although Mr. Smith has from time to time made various important alterations in the detail of the operations by which his system is to be carried out, he has in no way deviated from his original principle of growing this crop year after year in the same field; the land being subdivided into alternate strips of crop and fallow, the portion cropped one year being fallowed the next, and so on. A great number of intelligent agriculturists have visited the Lois Weedon farm, and, after an inspection of the crops growing on the plans there adopted, have generally been satisfied that the produce has been what the published accounts had stated it to be. Yet it is somewhat singular that those who have endeavoured to follow the directions given, on other soils, have generally been unsuccessful.

The object of the present paper is to give an account of some experiments which have been in progress for several seasons past, with a view of testing the applicability to the Rothamsted soil of the system described in '*A Word in Season*.' And besides discussing the experiments themselves, we propose to consider some points of interest which the principle of the Lois Weedon system involves; for although doubts may be entertained by practical men as to the possibility of *cultivating* large farms on such a plan, it must still *be admitted that the* results which have been obtained *by the Rev. Mr. Smith himself*, are calculated to impress upon us

most important lessons regarding the rationale of admitted agricultural facts and practices. They teach us, too, how great, in certain kinds of soil, must be at once the inherent wealth and the power of accumulation and of yielding up to the growing crop the constituents upon which it feeds.

In the year 1851 about three acres were selected for our purpose, in a field adjoining that which has been devoted for so many years to the continuous growth of wheat with and without artificial or other manures. The soil of these fields is a heavy loam, with a subsoil of stiff reddish yellow clay, which rests upon chalk. The depth from the surface to the chalk is perhaps never less than six or seven feet, and frequently twice as much; the natural drainage is, however, good. These soils, without being of high, are still of good average quality, and capable of growing good wheat crops. They are well suited, therefore, to test the degree of applicability to other soils, of plans proposed for extensive adoption in the cultivation of that crop. The field selected was under wheat in 1850, and was a bare fallow in 1851, prior to commencing the Lois Weedon operations in the autumn of that year. For the first crop the land was ploughed and harrowed in the ordinary way, and then set out in three feet strips; of these, every other one was sown with three rows of wheat a foot apart, and the intermediate ones were left as *fallow spaces*, to be prepared for the second year's crop during the growth of the first. It will be seen, that, as each strip was three feet wide, and as the three rows at a foot apart would only occupy two feet, there were in fact *four*-feet fallow spaces, as is recommended by Mr. Smith in some cases, instead of only three, as adopted in his own practice.

The first sowing was in September 1851, and, not having the special implements since recommended for carrying out the plan on the large scale, the seed was *dibbled* in, at a distance of two to three inches apart in the rows. One portion of the experimental ground had a single seed dropped into each hole, thus conforming, as far as possible, to Mr. Smith's mode of sowing single seeds at two to three inches apart in lines made with his presser; another and larger portion of the plot had two seeds in each hole. It was found that the *one-seed portion* took little more than half a peck of seed per acre, that is, half a peck to the moiety of the acre seeded at one time. The Rev. Mr. Smith, however, seems always to have calculated upon two pecks of seed being used, even though sown, as above described, in single grains, at two to three inches apart in the rows. And although, where we sowed two seeds in each hole, or twice as much as is recommended, we got on little more than a peck to the acre, yet it is but justice to Mr. Smith *to state*, that he now finds a more liberal seeding necessary for *safety and* security from blight, to which, as will afterwards be *seen*, our produce obtained on this plan was so subject.

may here be further mentioned, that not having the special ements—the "*presser implement*," the *drill* "*to drop seed by into the hard channels*," the "*roller implement*," the "*horse-hoe ment*," and the "*scarifier and harrow implement*"—which ecommended in Mr. Smith's later editions for carrying out his on an extensive scale, we were obliged to adopt his *earlier* ods, by which, however, his records show, that he obtained as , if not as economical results, as by his later ones.

efore the adaptation of special implements, Mr. Smith's plan prised "one double digging," "two single diggings, with " "pressing, sowing, hoeing," &c.

he following is a concise statement of the operations carried t Rothamsted, for each of the four crops respectively, which been obtained in the course of this experiment. And it may be premised, that one of the three acres was, for the sake of parison, set apart for alternate wheat and summer fallow—allow being cultivated according to the common custom of neighbourhood.

First Crop, 1851-2:—

heat, harvest 1850; summer fallow 1851; ploughed, har-d, &c., in the ordinary way, and sown with *one seed*, and *two* , as above described, September 1851; hand-hoed twice, and led as other crops. Crop foul, poor, and much blighted; n August 1852.

ommon fallow acre all sown autumn 1851; seed drilled at ate of about two bushels per acre, in rows 9 inches apart; l and weeded as usual. Crop heavy, but somewhat blighted.

Second Crop, 1852-3:—

he fallow intervals, which were not sown, trenched 14 to 15 es in December 1851; forked in spring, and again before ng; occasionally spudded, but became foul and crusted over ng the summer. Seed sown as for first crop, October 1852; l twice, and weeded as usual. Crop not clean, poor, and ated; cut September 1853.

ommon fallow acre, all fallow in 1852-3.

Third Crop, 1853-4:—

ubble of harvest 1852, trenched 14 to 15 inches December ; forked in the spring; spudded occasionally, and again ed before sowing. Sown as above, October 1853; hoed , and weeded as usual. Crop pretty clean, but poor, and ated; cut September 1854.

ommon fallow acre all drilled, as before; hoed and weeded as l. Crop very heavy, somewhat blighted.

Fourth Crop, 1854-5:—

ubble of harvest 1853, trenched 14 to 15 inches in winter

1853; forked in the spring; occasionally spudded, and scarified before sowing. Seed sown as usual, September 1854; twice hoed, and weeded as usual; moulded up with the plough in June. Crop clean, but poor, and blighted: cut September 1855.

Half only, of common fallow acre, drilled as usual for season 1854-5; hoed and weeded as usual. Crop small, but much less blighted than before.

In the following Table (I.) are given the results—

Of the four years' trial of the Lois Weedon plan; one portion with "*one seed*," and another with "*two seeds*," in each hole.

Of the "*common fallow*" acre, drilled with about two bushels of seed per acre.

And, for the sake of comparison, the produce in each of the four years, of the continuously unmanured and continuously cropped portion, in the adjoining experimental field.

This Table (I.) shows, that in each of the four years a larger crop was obtained where *two seeds* were sown in each hole than where *one* only was sown; and a reference to the weight per bushel, proportion of offal corn, and proportion of corn to straw, will show that the "*two-seed*" crop was also invariably somewhat better as to quality. As before observed, however, it is only due to the Rev. Mr. Smith to say, that "*for the sake of the sample and for safety sake*," he now recommends the seed to be sown thicker than he did formerly; though even in the later editions of the '*Word in Season*,' he still advised that the seed should be dropped singly, at two to three inches apart in the rows. But, even with the *two seeds*, the crop is in every case quite insignificant; and it should be noticed that it is only in the first year—that is, before the subsoil was brought up—that this thin dibbled crop was larger than the comparatively thickly drilled one on the continuously cropped and continuously unmanured plot in the adjoining field. Further, comparing the best of the two, namely the *two-seed* crop, with the drilled one after common fallow, we find that the latter in each year gives from twice to thrice the amount of produce of the former.

With regard to the drilled crop on the common fallow, it should be remarked that, in the first season (1851-2), the whole acre was sown; in the second season the whole acre was fallow; and in the third the whole was again sown. But, as this plan only gave a crop for comparison every other year, the plot was divided into two portions after the harvest of 1854, which were to be cropped or fallowed alternately. Comparing together the produce of this *common fallow portion*, with that of the *continuously unmanured plot in* the adjoining field, we see that, in 1852, the common fallow *gives nearly* three times the most produce; in 1854 it gives rather

Harvests 1852, 1853, 1854, and 1855.

Seasons.	Description of Plots, &c.	Particulars of Quantity.					Particulars of Quality.		
		Dressed Corn per acre in Bushels, Pecks, &c.	Dressed Corn per acre in lbs.	Offal Corn per acre in lbs.	Straw, Chaff, &c. per acre in lbs.	Total Produce per acre in lbs.	Weight per Bushel in lbs. and tenths.	Proportion of Offal Corn to Dressed as 100.	Proportion of Corn to 100 Straw.
1851-2.	1, 2, 3 First Year (after Common Fallow) "One seed"	10 0½	515	135½	1866	2516	51 0	26·3	34·8
	1, 2, 3 First Year (after Common Fallow) "Two seeds" ..	15 2½	795	175	2309	3279	51·0	22·6	42·1
	1, 2, 3 First Year (after Common Fallow) Drilled	37 0	1901	187	4934	7022	53·0	9·8	42·3
	Adjoining Experimental Field Continuously unmanured ..	13 3½	782	77¾	1597	2457	56·6	9·9	53·9
1852-3.	1, 2 Trenched, Forked, &c. "One seed"	4 0½	211	48½	796	1055	52·0	20·6	32·0
	1, 2 Trenched, Forked, &c. "Two seeds" ..	5 1	275	46¼	941	1262	52·6	17·5	34·5
	3 Common Fallow .. .. (No crop)	..	..	..	..	..	..	..	..
	Adjoining Experimental Field Continuously unmanured ..	5 3½	266	93	1413	1772	45·9	35·0	25·4
1853-4.	1, 2 Trenched, Forked, &c. "One seed"	11 1	661	56	1078	1795	58·6	8·5	66·5
	1, 2 Trenched, Forked, &c. "Two seeds"	14 2½	868	48	1368	2284	59·5	5·5	67·0
	3 Common Fallow .. .. Drilled	42 0	2541	168	4545	7254	60·5	6·6	59·6
	Adjoining Experimental Field Continuously unmanured ..	21 0¼	1277	82	2137	3496	60·6	6·4	63·6
1854-5.	1, 2 Trenched, Forked, &c. "One seed"	4 3¾	264	63¼	696	1023	53·0	23·9	47·1
	1, 2 Trenched, Forked, &c. "Two seeds"	6 1¾	350	69	803	1222	54·4	20·0	52·2
	3 After Wheat .. .. .. Drilled	17 1½	1006	74½	1734	2814	57·8	7·4	62·3
	Adjoining Experimental Field Continuously unmanured ..	17 0	1007	65¾	1787	2860	59·2	6·5	60·0

C 2

more than twice as much; and, as we shall see in the next Table, in 1856, it gave once and a half as much as the continuously cropped and continuously unmanured plot.

In contrast to these very marked effects of *fallow*, it is interesting to observe, that when in 1855 this common fallow plot grew wheat *after wheat*, the produce was, within half a bushel of corn and within half a hundredweight of straw, the same as was obtained on the continuously unmanured plot of the adjoining field in that same season, which was the twelfth in succession of wheat on that plot. So perfect an illustration could hardly have been expected, of the fact of the equal *wheat-growing condition* to which these two adjoining fields were reduced by the growth of the crop; or, what is the same thing, of the absolutely equal condition for practical purposes, to which these two soils were brought, in relation to the climatic resources of growth of one and the same season.

Lastly, in regard to these effects of *fallow*, it may be noticed that in no case is the amount of produce found to be equal simply to the sum of the continuous unmanured produce of the season of the fallow and of that of the succeeding crop. That is to say, the *produce after fallow* is not simply the produce of that particular season, taken together with that of the immediately preceding season. It is the result, not only of the unexpended resource of the fallow year, and of the resources (atmospheric and terrestrial) of the actual season of growth, but there is also an effect of the season of growth (whether for increase or decrease), reacting itself upon a two years' resource; and consequently, throughout the season, upon a different stage of progress and area of food collectors of the growing plant. Or, the difference between the actual produce after fallow and the simple sum of the produce of the two years may further depend upon the more or less favourable adaptation of season as regards the *healthy development* of the crop, as distinguished from the *mere amount* of the available resources of the soil and seasons.

But with this very marked increase of crop as the result of the common fallow, how is it that the more expensive processes of trenching and forking, with the thinner seeding, &c., which on the soil at Lois Weedon yielded such excellent results, have on the Rothamsted soil been so ineffective?

Undoubtedly the too thin seeding has been one cause of this. It is also certain that the same amount of labour expended upon the Rothamsted soil as upon the Lois Weedon one, was quite inefficient to get the same amount of staple and of exposure of surface to atmospheric influences. It may be here stated, however, that the trenching at Rothamsted cost on the average about once *and a half* as much as is estimated by Mr. Smith. It is granted

t the more recent recommendation, namely, that of g up the growing crop in June, was only adopted in the r of the experiment (1855), and then with little effect. he earlier recorded success at Lois Weedon was obtained this—however great the improvement, as undoubtedly certainly was not an essential in the original plan.

these unfavourable circumstances admitted then, we k, what is the rationale of the failure, which these circes have had their share in causing? Was the available food for the crop deficient in this turned-up raw clay with the good upper staple, weathered perhaps for cenow turned below for the descending roots to play in? it rather that the upper staple being now buried, or termixed with the subsoil, there was rendered available own, and from fresh atmospheric resources, less of the atmospheric food of the crop; and that the raw subt recently exposed to direct atmospheric influences, , so to speak, to prepare for the plant, and to accumulate an available form, also less of the normally atmospheric lants?

ommunicating our failure after four years' trial to the . Smith, he suggested the probability that it was due to f a sufficient amount of the *mineral* constituents of the lant being rendered soluble and available; and that, in , the requisite supply of mineral matter should be made nanure; believing that then, the soil having become d and porous, there would be an abundant supply of ubstance provided by the atmosphere.

the soil in question was not relatively deficient in soluble ilable mineral food, and that, under certain circumthere was provided an abundant supply of organic food y much larger crop, was proved much more conclusively by uce of the common fallow acre than any analysis of the d prove it. To test, however, in another way, what was re of the deficiency of the two-acre plot, trenched to a 14 to 15 inches and afterwards forked, it was, after the f 1855, divided into four portions, in such a manner that he four had an equal proportion of the trenched and forked d of the stubble ground. The whole was then ploughed ared for sowing in the ordinary way: one portion was anured, the second received mineral manure only, the moniacal salts only, and the fourth both mineral con- and ammoniacal salts. All four of the plots, together f of the common fallow acre by their side, were then vith about two bushels of seed per acre in the ordinary

In the following table are given the results of this experiment, obtained in the season 1855-6 just passed. For the sake of comparison, there is first given, in the *upper portion* of the table, the average annual result for the four previous years, of the "*one seed*," of the "*two seed*," and of the "*drilled common fallow*" plots; and also the average for the same years, of the continuously unmanured plot in the adjoining field. And, in the *lower portion* of the table, is given the produce at the last harvest (1856), in the adjoining field (where wheat is grown year after year without or with similar manures successively), of the continuously unmanured plot, and of the plots having the same manures as those now applied to the Lois Weedon plots. The manuring of the plots was, per acre, as under:—

1. *Unmanured.*
2. *Mineral Manures only.*

300 lbs. sulphate of potash.
200 „ „ soda.
100 „ „ magnesia.
200 „ calcined bone.
150 „ sulphuric acid (brown).

3. *Ammonia Salts only.*

200 lbs. sulphate of ammonia.
200 „ muriate of ammonia.

1. *Minerals and Ammoniacal Salts.*

300 lbs. sulphate of potash.
200 „ „ soda.
100 „ „ magnesia.
200 „ calcined bone.
150 „ sulphuric acid (brown).
200 „ sulphate of ammonia.
200 „ muriate of ammonia.

Looking at the *middle division* of the table, which shows the effects of manures, &c., on the trenched and forked land, and also the produce on the common fallow portion, it must be borne in mind that, in point of fact, rather more than half of the former was fallow, and less than half of it under crop, in the previous year; and that, moreover, smaller amounts of produce had been taken from this than from the common fallow portion during the four previous years. In comparing, therefore, the produce now obtained by thicker sowing, manure, &c., on this land with that on the common fallow plot, we must remember that the former was also in great part fallowed, and that the whole of it was less exhausted by previous cropping than the common fallow portion. Keeping this in mind, it is seen that the unmanured, trenched, and part-fallow portion, gave within a bushel as much corn, and *actually* a few pounds more straw and more total produce than the

	Corn; in Bushels, Pecks, &c.	Corn; in lbs.	Corn; in lbs.	Chaff, &c.; in lbs.	(Corn and Straw); in lbs.	Increase; in lbs. and tenths.	Of Offal Corn to Dressed as 100.	Of Corn to 100 Straw.
Lois Weedon, Common Fallow, and continuously Unmanured Plots.—Average Annual Produce, 1852, 1853, 1854, and 1855.								
1. } Trenched, Forked, &c. .. { "One seed"	7 2¼	413	75¾	1109	1597	53·6	19·8	45·1
2. } { "Two seeds" ..	10 1¾	572	84½	1355	2012	54·4	16·4	48·9
3. Common Fallow .. Drilled	*19 3	*1110⅓	*88¾	*2369¾	*3569	56·½	8·0	50·6
4. Adjoining Field .. Continuously unmanured	14 1¾	833	79¾	1733	2646	55·9	14·5	50·7
Lois Weedon Plots; with Artificial Manures, and 2 bushels of Seed Drilled.—Harvest 1856.								
1. Unmanured	21 0	1251	129	2147	3527	59·6	10·3	64·3
2. Mineral Manures only	23 2	1434	100	2431	3965	61·0	7·0	63·1
3. Ammoniacal Salts only	35 1¼	2069	188¾	3842	6100	58·6	9·1	58·8
4. Minerals and Ammoniacal Salts	41 0½	2430	133¾	4904	7468	59·1	5·5	52·3
5. Common Fallow Plot—Unmanured	21 2¾	1302	86½	2113	3501	60·0	6.6	65·7
Adjoining Experimental Field; 13th Season of Wheat year after year.—Harvest 1856.								
1. Unmanured	14 2	789	103¼	1558	2450	54·3	13·1	57·3
2. Mineral Manures only	18 3¼	1062	104¾	2012	3179	56·4	9·9	58·0
3. Ammoniacal Salts only	24 0¾	1343	162½	2818	4323	55·5	12·1	53·4
4. Minerals and Ammoniacal Salts	37 1	2159	152¼	4560	6871	58·0	7·0	50·7

* This should be the average for the four years, of what the whole acre would yield, on the supposition that only half of it was cropped each year. It is obvious, however, that as the whole acre was cropped after fallow in the first and third years, instead of half only in each of the four years, no exact comparison can be drawn. In fact, the seasons of the 2 crops after fallow were more favourable than those of the other 2 years, and hence the averages in the Table will be relatively somewhat too high for the four years of the Lois-Weedon-plan produce; though it should be remembered on the other hand, that the 4 years' produce on the Lois Weedon plan had the benefit of the previous year's fallow, and hence was the result of 5 years' resource. The following is, however, an example of the method of calculation adopted as perhaps the best under the circumstances:—

"Total Produce" of whole acre . . . . . 1852 = 7,022 lbs.
" " . . . . . 1854 = 7,254 "
4) 14,276 "
3,569 "

common fallow. It is evident, therefore, that the less produce on the trenched portion in the previous years, was in greater measure due to the thin seeding on the comparatively poor and raw turned-up subsoil, than to any relative deficiency or want of available condition of the food of the plant within the soil—*provided only* that a sufficiently healthy early development, and a sufficiently wide distribution of the underground feeders of the crop, were but obtained.

Taking the produce of this unmanured portion thus explained, as the standard by which to compare the effects of manures on land in the same condition, we find that—

"*Mineral manures only*"—gave an increase of not quite 2½ bushels of total corn, and of only 284 lbs. of straw.

"*Ammoniacal salts only*"—gave an increase of about 15 bushels of total corn, and of 1695 lbs. of straw.

"*Minerals and ammoniacal salts*"—gave an increase of rather more than 20 bushels of corn, and of 2757 lbs. of straw.

These striking results can leave no doubt that the *mineral* supplies in the soil in question were far in excess over the available and assimilable nitrogen. A comparison, too, of the middle and the lowest divisions of the Table will show that, if we take into consideration the very different condition of the land in the two cases, the effects of these manures on the Lois Weedon or trenched plots, were perfectly consistent in kind (though of course not equal in degree) with those of the same manures in the adjoining field, where they have been applied, and the crop has been grown, for many years in succession.

Hundreds of other experiments, and the whole range of recorded agricultural experience, conspire to show, that in ordinarily cropped and cultivated soils, the available mineral supplies are generally in excess relatively to the available supply of nitrogen of the soil and season, in the case of the wheat crop: in fact that, excepting in cases of very special and unusual exhaustion of the mineral or soil-proper constituents, the direct supply of them by manure for wheat does not increase the crop in any practicable and agricultural degree, unless there be a liberal provision of *available and assimilable nitrogen within the soil.* The results given above are a remarkable illustration of this. Thus, when the mineral constituents alone were added to this part fallow and only part crop-exhausted land, they gave an increase of only 438 lbs. of total produce; but when the same mineral constituents are added to the same soil with *ammoniacal salts*, the increase over and above that by ammoniacal salts alone is 1368 lbs., instead of only 438 lbs. Here, too, is a sufficient incidental proof that the minerals were added in an *available form*;—indeed, that they only required sufficient available nitrogen within the soil to yield a larger crop than

uld be obtained in the average of seasons on such soil by the linary means of farming.

But turning now from the effect of the *mineral* constituents to t of *assimilable nitrogen* in manures, we have in these simple periments the best answer—namely, that of direct contrary t—to those who would endeavour to persuade the farmer, that ause the soil itself contains hundreds of times more nitrogen n the largest crop of wheat, therefore the comparatively small ntity which is added in an ordinary dressing of manure can e little or no effect. We shall recur to the subject of the ogen in soils further on, should our allotted time permit it. In mean time let it be prominently noted, that whilst the *minerals* ne gave a total increase of only 438 lbs., the *ammoniacal salts* ne gave 2573 lbs. of increase! And again, whilst the addition ninerals to ammonia gave an increase of 1368 lbs., the addi- n of ammonia salts to minerals, on the other hand, gave an ease of 3503 lbs.!

here can now be little difficulty in deciding, that it was no ciency of available mineral food merely, which prevented the nt for itself, or the soil in the first instance for it, from uiring a sufficiency of available and assimilable organic con- uents for the growth of a very much larger crop than was in obtained from this expensively cultivated land. It was, on other hand, notwithstanding the "inexhaustible" supplies of atmosphere, and notwithstanding the enormous amount of ogen in the soil in some form—it was, notwithstanding these deficiency of *available and assimilable nitrogen within the soil*, ich restricted the full action of the obviously available minerals, which hence restricted the produce also, to an amount below average of farming. Whilst, only make up this deficiency of ilable nitrogen, and the produce is increased to once and a f or twice as much.

t appears, then, that the same means which afforded the Rev. Smith his early success on the soil at Lois Weedon, were te incompetent to yield a similar result on the soil at Rotham- l. Nay, these same means, notwithstanding that in our case they e much more costly than either Mr. Smith had found them, or n the common fallow which we tried by their side, did not n attain, for the Rothamsted soil, those mechanical conditions, hout which the necessary actions between soil and atmosphere ld not be expected to take place. We think it indeed very btful whether, even if all the more recent improvements in plan could have been fully carried out at Rothamsted, a lt would have been obtained there at all equal to that at Lois edon. Certain it is, that soils and subsoils, which may equally included as "*clayey*" or "*heavy*" or "*loamy*," vary almost

infinitely in degree, in physical character and texture, and in chemical qualities, under the influence of similar management and of equal climatic circumstances. We think, therefore, that considerable caution should be exercised in the application to various descriptions of land, of plans which peculiarly rely for their success on qualities of soil which are admittedly so variable in the degree of their activity.

Leaving the question of the field-experiments, let us now turn to a brief consideration of some points of great practical interest and importance, which a careful study of the relations of soil and atmosphere to produce, and of the success at Lois Weedon, cannot fail to suggest.

The main peculiarity of the Lois Weedon system of growing wheat is, that it develops to the utmost (chiefly by mechanical means), and relies exclusively upon, the resources of the soil and atmosphere, without the aid of manure: that is to say, it is sought, by the means employed, so to increase the depth of staple, and the area of distribution of the underground feeders of the crop, and so to increase the surface annually exposed to climatic influences, as to cause, not only a greater annual liberation of mineral constituents from the otherwise locked-up stores of them in the soil itself, but also a greater accumulation and elaboration, throughout its more porous and root-searching area, of the normally atmospheric food of plants, and particularly of nitrogen, in an available and assimilable form.

The principle of relying upon the stores of the soil alone, without return, for the mineral food of successive crops, is directly opposed to that laid down for the guidance of the agriculturist in No. xxxvii. of the *Journal of the Royal Agricultural Society*, by Baron Liebig. He says:—

"Their heavy crops will perhaps not be rendered heavier by the restoration of all the mineral constituents, but they will at all events be rendered *permanent*. We shall never have a rational agriculture until, by such experiments, the law of the fertility of the soil, in reference to time, has been brought home to the minds of agriculturists."—*Journal*, p. 313.

The conclusion of the Rev. Mr. Smith, looking from the practical as well as the scientific side of the question, goes rather in a different direction. He says to his readers:—

"The assertion is, that, on wheat land,—that is, on the great majority of clays and heavy loams,—no manure is required for wheat on this plan, since its food in abundance is there already."—*Lois Weedon Husbandry*, pp. 102-3.

And again (ibid. 103-4), referring to chemists, he says to his readers:—

"Ask them plainly, whether the soil and subsoil of clays and loams, generally though not universally, do or do not contain all that is wanted as *mineral food* for the wheat? Ask them, further, whether tillage, and pulverisation, and gradual exposure, and annual fallows, will not render soluble sufficiency of these substances for your annual need? If they reply, 'Yes,' ut demur to the plan, and add, that in time it will exhaust the capital of he land,—ask them once more, 'In how long a time?' And if they answer, Why, in some cases, in a thousand years or more, in others five hundred, and n some a hundred;' your rejoinder must be a smile; for you would surely feel, hat even a hundred years' supply should satisfy living man."

Baron Liebig, in the article above referred to, also indignantly repudiates the notion that the cause of the efficacy of *fallow* is to be looked for in the increase of the amount of ammonia in the soil, or that any specially predominant influence was to be ascribed to the ammonia which the soil acquires in fallow. The Rev. Mr. Smith, on the other hand, speaking of the "*organic*" food—"carbonic and nitric acid and ammonia"—asks, "do not the pulverised intervals of the wheat, in the annual fallow, absorb and retain it for use?"

It is rather curious, that, with such vital inconsistencies of principle and opinion, the wheat-growing operations and success at Lois Weedon, and Mr. Smith's interpretation of them, should subsequently have been brought forward in confirmation of the particular views of Baron Liebig. The means by which Mr. Smith obtains his large crops of *roots* also, have recently been adduced * as refutation of the views on such points emanating from Rothamsted. But the writer in question appears, as the case, to misstate the extent and bearing of every conclusion, and even facts, which may happen to come from Rothamsted. For our own part, careful observation and inquiry on more than one visit to the spot, as well as the perusal of Mr. Smith's publications, lead us to say, that we know of no experience more calculated to confirm the opinions we have held in this Journal regarding the requirements of growth of full crops of wheat on the one hand, and of roots on the other, than that at Lois Weedon.

But to return. The question is of vital importance to practical agriculture, however little it may interest or affect the researches of "chemists and men of science,"—what is the characteristic nature of the exhaustion induced by the growth of the most important crop of the farm? And, we may add,—whether or not soils generally, or soils of any particular class, are competent, without injury, to sustain an annual extraction of mineral constituents, and to liberate, or (either by themselves or by the plants growing on them) newly to acquire from the atmos-

* Journal of Agriculture of the Highland and Agricultural Society of Scotland, July 1856.

phere, a sufficiency of nitrogen for full crops, in an available and assimilable form?

Certainly, if we were to rely upon the mean results of the 42 analyses referred to by Baron Liebig (in No. xxxvii. of the *Journal of the R. A. S.*) in illustration of the amount of nitrogen contained in soils, we should be led to conclude that many soils, at least, had enough of the mineral constituents of our crops for thousands of years, under the ordinary practices of *rotation*, and for hundreds of years of the growth of wheat on the Lois Weedon system. Almost all other published analyses of soils would lead to a similar conclusion; in fact, we know of scarcely any that would not. It must be freely confessed, however, that the methods by which soils have hitherto generally been analysed, have proved themselves, in their results, to be little fitted to afford the information for which the analyses were undertaken. Nevertheless, judging from the whole of the evidence of this kind at command, it may perhaps safely be concluded that, excepting the one constituent phosphoric acid, the greater proportion of soils which are termed "*heavy*," "*clayey*," or "*loamy*," do *contain*, within a workable depth, a sufficiency of mineral constituents for thousands, or hundreds, of years, as above supposed. It is, however, by no means so clear that many of them would not fall short rather in *annual liberation in available form*, than in *actual percentage amount* of the necessary mineral constituents. Indeed, there is evidence enough in agricultural experience to show that, although the ordinary practice of rotation leaves, in most soils, a balance of *available* mineral constituents, and therefore demands a supply of nitrogen from without, yet, with this supply *alone*, the point of the requirement of more immediately available mineral constituents for full and healthy crops is in its turn frequently soon arrived at. In fact, it is the "*condition*," both as regards mineral and nitrogenous supplies, rather than the *actually existing* amount of them in the soil, that becomes defective. And in the lighter soils more especially it is, that the *condition* as regards the mineral constituents of our crops, or the *floating capital* so to speak, both bears a much larger proportion to the available stores of the soil itself, and is more dependent on restoration or supply from without.

In Mr. Smith's "*heavy land*," with its clayey subsoil intermixed, disintegrated, and well weathered (and perhaps even in his "*light* land," with its dressing of marl), it is quite clear, from the continued good results, that the annually available mineral supply, or the mineral *condition*, is not at present impaired; nor, so far as existing knowledge of such matters can be relied upon at all, need Mr. Smith be alarmed lest the dormant *stores*, at least of his heavy soil, should not last the century

hich, he says, should satisfy living man. And it should be orne in mind, that the resources of the soil are not to be spoken f, as some are wont to do, as sufficient for—say fifty or a hun-red crops, and to be cleared off to the *zero point* at pleasure, in alf or double the number, accordingly as the soil is supplied with ther elements of growth. Whatever the actual stores of the soil, hey are only little by little available; and it is not easy to sup-pose that a heavy soil, yielding, under proper management, nnually enough for large crops over a continuous series of ears, does not contain a correspondingly enormous store in the ormant state. Whether, however, the same soil would annually ield an equal supply of available minerals if its surface were ess exposed to weathering influences, and the required nitrogen or full crops were provided by manure, is quite another uestion.

But now let us turn, as briefly as possible, to a consideration of the nature of the evidence which analysis affords, of the amount of nitrogen contained in soils, and then, equally briefly, to a review of some of the circumstances which seem to have their share in the production of the large annual crops of wheat, without manure, at Lois Weedon.

As is well known, in 1843 Baron Liebig laid more stress than formerly on the sufficiency of the assimilable supplies of nitrogen in the atmosphere; and a few years later, after having before him the analyses of a number of soils made in his laboratory by Dr. Krocker, he superadded to the argument of the inexhaustibility of the supplies of the atmosphere, that of the large amount of nitrogen contained in soils themselves, to show that little or no effect could be attributed to the small proportion which is added in an ordinary dressing of manure; and to this he now adds, still more emphatically, in reference to fallow, that the accumulation of ammonia in the soil in one year has no influence on the crop in the succeeding year. With regard to the amount of nitrogen in the soil, we, in 1847, alluded to this point, and gave the percentage obtained by analysis of the surface-soil of the field upon which our experiments on wheat were being conducted. The necessary distinction to be drawn between the immediately available and the actually existing contents of the soil, as above referred to, was, however, too obvious to allow a moment's scepticism as to the influence of the small proportions of available nitrogen which, in our experiments, we superadded in manure. On this point, however, as it is very important to the farmer that he should be satisfied respecting it, we cannot do better than quote the replies to this argument of Baron Liebig by M. Boussingault, and by M. Kuhlmann; to the latter of whom Baron Liebig dedicates the fuller version of his paper in No.

xxxvii. of the *Journal of the R. A. S.*, which is published as an independent work in Germany.

M. Boussingault says,—

"Latterly, M. Liebig has sought to establish that the mineral matters, the alkaline salts, are the only efficacious agents of manures, supporting this assertion by analyses which indicate in arable land, even when unmanured, a considerable proportion of ammonia; from which it has been concluded that, the soil always contains a more than sufficient amount of nitrogenized matter, there is no necessity to supply them to it.*"

And further,—

"This alkali was determined by calcining the soil with a mixture of soda and lime. We know that, by this method, the nitrogenized substances are transformed into ammonia: but the process does not enable us to decide whether this ammonia was entirely formed in the matter examined. In fact, a soil might furnish by analysis a very large proportion of the volatile alkali, and yet we might not be justified in affirming that it contains, I will not say this alkali already formed, but even putrescible nitrogenized substances, that is to say those which are efficacious in vegetation. Thus we might extract from a soil abounding in peaty debris, from a bituminous schist, large quantities of ammonia, without, on that account, being sure of obtaining advantageous crops from such soils.

"However, it is according to the determinations of nitrogen, that M. Liebig states that a hectare of arable land, taken to a depth of 25 centimètres, contains, not the elements of ammonia, but 2000 to 10,000 kilogrammes of ammonia itself; a result presented as an objection against the necessity of the employment of nitrogenized manures. M. Kulhmann has remarked, with reason, that there is an answer to this objection in the facts themselves, and it is, that a hectare of land may contain enough of nitrogen held in stable combinations to represent as much as 10,000 kilogrammes of ammonia, and nevertheless give meagre crops, whilst, if dressed with 250 kilogrammes of ammonia in the form of manure, it will yield, after cultivation, a satisfactory produce." †

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* "Dans ces derniers temps, M. Liebig a cherché à établir que les matières minérales, les sels alcalins, sont les seuls agents efficaces des engrais, en appuyant cette assertion sur des analyses qui indiqueraient dans la terre arable, alors même qu'elle n'est pas fumée, une forte proportion d'ammoniaque; d'où l'on a conclu que le sol contenant toujours une dose plus que suffisante de matériaux azotés, il n'y a pas lieu de lui en fournir."—*Econ mie Rurale*, tome ii. p. 77.

† "On a dosé cet alcali en calcinant la terre avec un mélange de soude et de chaux. On sait que, par cette methode, les substances azotées sont transformées en ammoniaque; mais le procédé ne permet pas de décider si cette ammoniaque était toute formée dans la matière examinée. En effet, une terre pourrait fournir à l'analyse une très-forte proportion d'alcali volatil, sans que pour cela on fût en droit d'affirmer qu'elle contient, je ne veux pas dire cet alcali tout constitué, mais même des substances azotées putrescibles, c'est-à-dire, efficaces dans la végétation. Ainsi, on extrairait d'un sol abondant en débris tourbeux, d'un schiste bitumineux, de fortes quantités d'ammoniaque, sans que, pour cela, on soit assuré de retirer de semblables terrains des récoltes avantageuses.

"Cependant, c'est d'apres des dosages d'azote, que M. Liebig trouve qu'un hectare de terre arable, sur une profondeur de 25 centimètres, contient, non pas les élemens de l'ammoniaque, mais 2000 à 10,000 kilog. d'ammoniaque en nature. Ce résultat presente comme une objection contre la nécessité de l'intervention des *engrais azotés*. M. Kulhmann a fait remarquer, avec raison, qu'il y a à cet *objection* une réponse dans les faits mêmes, et c'est qu'un hectare de terre pe-

f. Kuhlmann himself says,—

Neither must the nitrogen be held in too stable combinations, as it exists
al, the direct employment of which does not conduce to the fertilisation of
oil, but which by distillation yields a very fertilising ammoniacal liquid.
ot the same reflections apply to an objection raised against the necessity of
mployment of nitrogenized manures; namely, that a hectare of land to the
h of 20 to 25 centimètres contains ammonia in quantities infinitely greater
those by means of which we seek to provide it with the elements of
lity? In my opinion, it is not sufficient that distillation should enable us
parate ammonia from the soil; it is necessary that this ammonia should be
sible to the plant without the aid of fire or of other energetic agents.
There is moreover a reply to the objections stated above in the facts
selves; a hectare of land may contain enough of nitrogen held in stable
inations to produce 5000 or even 10,000 kilogrammes of ammonia, and
give poor crops. If we apply to the same land 250 kilogrammes of
onia, in the form either of ordinary manure or of pure ammoniacal salt,
rtility will be doubled.
Agriculture is, above all, a science of facts; it is in experience that it must
the basis of its theoretical laws." *

hese, then, are the opinions of chemists as well known by
: investigations in the field as by their researches in the
ratory.

aving now to record some recent determinations of nitrogen
ils made at Rothamsted, it may be well first to dwell for a
ent on some of the previously published data of this kind
:h have been quoted by Baron Liebig. With regard to the
rmination of nitrogen in soils, made by Dr. Krocker in
, in the Giessen laboratory, it appears, by reference to the
nal paper (Annalen der Chemie und Pharmacie, Band 58,
381-8), that he only made a single determination on each of

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ir assez d'azote engagé dans des combinaisons stables, pour représenter
à 10,000 kilog. d'ammoniaque. et donner néanmoins des récoltes chétives,
que, fumé avec 250 kilog. d'ammoniaque à l'état d'engrais, il rendra, par la
e, des produits satisfaisants."—*Ibid.* p. 78.
Il ne faut pas non plus que l'azote soit engagé dans des combinaisons trop
s, comme cela existe pour la houille, dont l'emploi direct ne donne pas lieu à la
sation du sol, mais dont la distillation déplace un liquide ammoniacal très-
sant. Les mêmes réflexions ne s'appliquent-elles pas à une objection produite
la nécessité de l'emploi des engrais azotés; à savoir qu'un hectare de terre
u 25 centimètres de profondeur contient des quantités d'ammoniaque infini-
upérieures à celles au moyen desquelles on cherche à lui donner des élé-
de fertilité? Dans ma pensée, il ne suffit pas que la distillation permette de
er de l'ammoniaque de la terre, il faut que sans le secours du feu ou d'agents
ques cette ammoniaque puisse être offerte à la plante.
y a d'ailleurs à l'objection présentée ci-dessus une réponse dans les faits
. Un hectare de terre peut contenir assez d'azote engagé dans des combi-
s stables pour produire 5000 et même 10,000 kilogrammes d'ammoniaque
ner cependant des récoltes chétives. Si l'on fume cette terre avec 250 kilo-
nes d'ammoniaque à l'état d'engrais ordinaire ou de sel ammoniacal pur, la
té sera doublée.
'agriculture est, avant tout, une science de faits, c'est dans l'expérience
: doit chercher la base de ses lois théoriques."—*Annales de Chimie et de
ue*, vol. xx., 1847, *p. 271.*

the soils. We are therefore (though without calling them question) unable to form any such judgment from the resu themselves of the probable limit of error arising from ma pulation and other causes, as duplicate analyses would ha enabled us to do. And when it is borne in mind, that m of the published analyses show an amount of nitrogen in s only amounting to from one-tenth to one-quarter of 1 per ce it will easily be seen that slight errors of analysis, such in most subjects of investigation would be quite immater are here of the utmost consequence—if, at least, we sho wish to discuss, by the aid of such analyses, such differen between soil and soil, or between the same soil in the conditi in which it would yield respectively a given amount of c below a usual average, or a full one, equal to twice as much the former. In illustration of this, we need only say that 100 l of ammonia, added to an acre of soil weighing 4,000,000 l (and which every intelligent farmer knows would, on most so increase his crop enormously), would, if well mixed with bulk of soil, only raise its ammonia by 0·0025 *per cent.*—o part in 40,000. This fact should not be lost sight of in consideration of the figures which will shortly follow.

Next to the determinations of nitrogen in soils by Dr. Krocl as referred to above, the most extensive series quoted by Ba Liebig is that made at the instance of the Royal College of Ru Economy in Berlin. Baron Liebig introduces these results follows (and the italics in the second paragraph are his own):

"The fact of the presence of this enormous amount of nitrogen in the has been confirmed by the researches made at the instance of the Royal Col of Rural Economy in Berlin ('Annalen der Landwirthschaft,' vol. xiv., p The College of Rural Economy caused land of apparently uniform qualit be selected in fourteen different localities in Prussia for these experime At ten or twelve different points of each of these fields an equal quantit earth was taken by the spade from the entire depth of the arable soil; t portions, in each case, were thoroughly mixed, and from the mass sam were taken.

"In each sample the amount of nitrogen was determined *by three diffe chemists separately*, and from their results have been calculated for one ac land, to the depth of 1 foot (the specific gravity of the soil being taken at 1 the following quantities of nitrogen, expressed however in pounds of *amm* (17 lbs. of ammonia contain 14 lbs. of nitrogen)."—*Jour. Roy. Ag. Soc.* vol. xvii., part 1, p. 285.

As these determinations are introduced to the reader by high an authority in the matter of chemical analysis, as be made "*by three different chemists separately*," and as Baron Lie arranges the soils in the order of their richness in nitrog according to the *mean* of the three experiments for each soil may be interesting to examine what was the sort of agreem

between the results of the three experimenters on each of the fourteen soils. Accordingly there is given Table III., p. 22:—

In the upper portion, the percentages of nitrogen in each soil, as found by each of the three chemists, and calculated upon the soil dried at 100° C. (210° F.), are given. And—

In the lower portion of the Table, the calculated lbs. of ammonia per acre of 4,000,000 lbs.* of dry soil, according to the determinations of each separate experimenter, and also according to the mean of the three, are given. And in the last column are given, the lbs. per acre of ammonia for each soil as calculated by Baron Liebig.

So discrepant are the determinations of the three separate experimenters on the same soil in almost every case, that the results must be considered quite inapplicable as a means of arranging the soils according to their probable relative amounts of nitrogen. So great, indeed, is the discrepancy, that we find frequently once and a half or twice as much, and in several instances even ten times as much, recorded by one chemist as by another, for one and the same soil. In fact, in applying each of the separate analyses instead of the mean of the three, to estimate the amount of nitrogen or ammonia per acre, we find that one or two of the soils could be put both at the top and nearly at the bottom of Baron Liebig's list, accordingly as we select the determination of one or another of the experimenters; whilst in the same way, several others might be separated from one another by half the items in the list. It may even be a question, how far a judgment can be formed from such results, of the probable average or range of amount of nitrogen in the soils.

It is, however, only due to Professor Magnus, the able and conscientious reporter to the Royal College of Rural Economy in Berlin, of the analyses in which these nitrogen determinations are but items, to say that he called particular attention to the little agreement between the results of the different experimenters. In fact, his chief conclusion was, that as twenty-one of the best chemists in Germany, or of those working under the superintendence of the most distinguished chemists, had been selected, and as there could therefore be no want of technical knowledge devoted to the subject, it was obvious that in the existing state of science little was to be expected from the analysis of soils.

* The estimate of 4,000,000 lbs. of dry soil per acre, taken to the depth of one foot, is higher than we have been accustomed to take it; but we adopt it here, not only because it is a convenient round number, but because it obviously agrees very closely with the amount supposed by Baron Liebig, with whose estimates we are comparing our own figures. It is obvious that the cubic contents, and the weight of *available* soil on an acre, must vary extremely; so that any figure adopted in an estimate of this kind must be to a great extent arbitrary.

TABLE III. - Showing the Percentage of Nitrogen, and the supposed Ammonia per Acre calculated therefrom, in 14 Soils, each Analysed by three Chemists separately.

Nitrogen per Cent. in the Soils.

	By 1st Experimenter	By 2nd Experimenter	By 3rd Experimenter	Mean.
1. Havixbec	0·591	0·081	0·400	0·357
2. Burg Wegeleben	0·432	..	0·270	0·351
3. Turgaitschen ..	0·240	0·350	0·280	0·290
4. Wollup	0·200	0·298	0·271	0·256
5. Beesdau	0·137	0·249	0·108	0·165
6. Turwe	0·140	0·130	0·173	0·148
7. Dalheim	1·609	0·150	..	0·879
8. Laasan	0·112	0·113	0·138	0·121
9. Eldena	0·090 0·120	0·120	0·113	0·111
10. Burg Bornheim	0·102	0·114	0·113	0·110
11. Neuensund ..	0·147	0·103	0·010	0·087
12. Frankenfelde ..	0·079	..	0·093	0·086
13. Neuhof	0·130	0·154	0·011	0·098
14. Cartlow	0·076	0·106	0·005	0·062

Nitrogen calculated as lbs. of Ammonia per Acre of 4,000,000 lbs. of Dry Soil.

	By 1st Experimenter	By 2nd Experimenter	By 3rd Experimenter	Mean.	Ammonia in lbs. per Acre 1 foot deep, as given by Liebig.
1. Havixbec	28,704	3,932	19,428	17,352	18,040
2. Burg Wegeleben	20,980	..	13,112	17,048	17,200
3. Turgaitschen ..	11,660	17,000	13,600	14,084	14,350
4. Wollup	9,712	14,472	13,160	12,448	13,120
5. Beesdau	6,652	12,092	5,244	7,999	7,790
6. Turwe	6,800	6,312	8,400	7,172	7,380
7. Dalheim	78,151	7,284	..	42,716	6,970
8. Laasan	5,440	5,488	6,702	5,877	5,740
9. Eldena	4,371 5,828	5,828	5,488	5,377	5,390
10. Burg Bornheim	4,954	5,537	5,488	5,328	5,390
11. Neuensund ..	7,140	5,002	485	4,211	4,510
12. Frankenfelde ..	3,837	..	4,517	4,120	4,100
13. Neuhof	6,312	7,480	534	4,774	4,920
14. Cartlow	3,691	5,148	243	3,026	2,870

Concurring fully with Professor Magnus on this point, and believing that little advance will be made without previous special investigation and adaptation of methods of analysis to this particular subject, it is only with the reservation which such a conviction implies, that we would now record or apply the determinations of nitrogen in soils recently made at Rothamsted

rent methods. We may say, however, that every pre- s been taken to secure as much of accuracy as those re capable of. Nor are we wanting in evidence in the mselves, that within certain limits, and for the discus- me points of comparately broad distinction, they are r conclusive.

ollowing Table (IV.) are given the results of deter- of nitrogen—in the soil and subsoil of the plot devoted sted to the experiments on the Lois Weedon system— l of the continously unmanured plot, of the continu- eral-manured plot, of the continuously ammonia- lot, and of the continuously mineral and ammonia- lot, in the adjoining experimental wheat-field. There iven, the determinations of nitrogen in specimens of ubsoil, &c., from the Rev. Mr. Smith's experimental ois Weedon. And, for the sake of comparison with in Table III. last discussed, there is given in the lower the Table (IV.), the amounts of *nitrogen* (in lbs.) that contained in 4,000,000 lbs. (= an acre about a foot ie specimens analysed—both according to the individual nd to the mean result for each specimen. In the last e mean acreage amount of nitrogen is represented in its amount of ammonia. It is obvious, however, that no is represented by thus applying the analyses of soils ls indiscriminately, to a supposed equal acreage weight each case. The figures are only useful as conveying eral comparative idea, of about how much ammonia, valent of nitrogen, would exist in a layer of one acre bout a foot thick, of soils or subsoils containing a given amount.

be remarked, too, that whilst the specimens of sur- at Rothamsted were each taken at eight different l as nearly as possible to a depth of nine inches and a foot square, the whole being then well mixed and l, those at Lois Weedon were each taken at one spot od spit of depth being the only condition attended to. t both places were collected during the present year ose at Lois Weedon in August, and most of those at d in September.

ses the soils were broken up and turned over and the s picked out; they were then further reduced and from smaller stones. Finally, they were rubbed to er and passed through a fine sieve, in which state submitted to analysis. In these processes of prepara- ils were never submitted to a temperature above 60° to l when so prepared they generally retained less, or little

TABLE IV.—Showing the amounts of Nitrogen (exclusive of Nitric Acid) in Rothamsted and Lois Weedon Soils and Subsoils.

Nitrogen per Cent. in the Soils, calculated as Dry.

		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 4.	Mean.
Rothamsted	Lois-Weedon-Plot Surface Soil	0·1416	0·1418	..	..	0·1417
	Lois-Weedon-Plot Subsoil	0·0730	0·0763	..	..	0·0746
Rothamsted Surface Soils, adjoining Experimental Field	Unmanured	0·1560	0·1450	0·1560	..	0·1523
	Mineral Manure ..	0·1430	0·1529	0·1420	..	0·1459
	Ammoniacal Salts ..	0·1530	0·1694	0·1620	0·1505	0·1587
	Minerals and Ammoniacal Salts ..	0·1520	0·1593	0·1545	0·1567	0·1556
Lois Weedon	Heavy Land Stubble	0·1640	0·1590	0·1670	0·1666	0·1641
	Heavy Land Fallow	0·2020	0·1940	0·2000	0·2090	0·2012
	Light Land Fallow	0·1630	0·1520	0·1510	0·1540	0·1550
	Heavy Land Subsoil	0·0661	0·0670	0·0667	0·0610	0·0652
	Light Land Subsoil	0·0840	0·0770	0·0760	0·0760	0·0782
	Marl Pit					
	Light Land Field ..	0·0920	0·0890	..	..	0·0905
	Rye-grass Subsoil, with Liquid Manure	0·0790	0·0790	..	..	0·0790
	Heavy Land Field					

Nitrogen per Acre about 1 foot deep—taken at 4,000,000 lbs. Dry Soil.

		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 4.	Mean.
		lbs.	lbs.	lbs.	lbs.	lbs.
Rothamsted	Lois-Weedon-Plot Surface Soil	5,664	5,672	..	..	5,668
	Lois-Weedon-Plot Subsoil	2,920	3,052	..	..	2,984
Rothamsted Surface Soils, adjoining Experimental Field	Unmanured	6,240	5,800	6,240	..	6,092
	Mineral Manure ..	5,720	6,116	5,680	..	5,836
	Ammoniacal Salts ..	6,120	6,776	6,480	6,020	6,348
	Minerals and Ammoniacal Salts ..	6,080	6,372	6,180	6,268	6,224
Lois Weedon	Heavy Land Stubble	6,560	6,360	6,680	6,664	6,564
	Heavy Land Fallow	8,080	7,760	8,000	8,360	8,048
	Light Land Fallow	6,520	6,080	6,040	6,160	6,200
	Heavy Land Subsoil	2,644	2,680	2,668	2,440	2,608
	Light Land Subsoil	3,360	3,080	3,040	3,040	3,128
	Marl Pit					
	Light Land Field ..	3,680	3,560	..	..	3,620
	Rye-grass Subsoil, with Liquid Manure	3,160	3,160	..	..	3,160
	Heavy Land Field					

1 5 per cent. of water separable by further drying at
or convenience and uniformity, the determinations in
are all given as calculated upon the soil so dried at
ugh separate portions were always employed for the
tion of the moisture in this way, and those of the
rere always made upon the partially and only air-dried

rogen determinations were made by burning with soda-
ecting the ammonia in hydrochloric acid, and estimat-
tinum salt in the usual way. It is obvious that this
es not give that portion of nitrogen which may exist
acid. But from the interesting results of Professor
the power of soils to absorb ammonia and nitric
ctively, and on the general relation of these two sub-
drainage-water, it may perhaps safely be concluded
ost ordinary soils, but a very small proportion of their
f nitrogen will be retained as nitric acid.

o, three, or more determinations upon each soil, were
e or two cases made by the same analyst; two persons
ployed upon the series, each, as a rule, making two
ions upon the same specimen. In this way it was
iminate any prevailing tendency to high or to low results
ght attach to the work of either operator. It is
it would be the opinion of most chemists, that the
ies in the percentage amounts of nitrogen which the
ibits, are neither greater nor more numerous than were
cted in the manipulation of the process employed, by
tors on such a series. When, however, it is remem-
, as already pointed out, the large dressing of a hun-
ds of nitrogen per acre, distributed through the soil to
of 1 foot, would only raise its percentage of nitrogen
, equal $\frac{1}{7000}$th of its weight, it would at once be
he separate determinations on the same soil frequently,
ally, differ much more from each other, than would the
before and after such a potent manuring. It is clear
this simple illustration, that such methods of estimat-
trogen in soils are quite inapplicable to determine the
in this respect between a soil yielding 16 bushels of
out manure, or twice, or twice and a half the amount,
That is to say, such methods are quite incompetent
to treat the question of the mere *temporary* "*condi-*
oils.

ng then all due caution, on the score both of the diffi-
irly and uniformly sampling soils for analysis, and of
urately determining the nitrogen by current methods,
what are *some of* the more general indications of the

Table. For this purpose we take of course the *mean* results instead of the separate determinations; which latter, however, although disagreeing with each other sufficiently to show that the figures could not be relied upon to treat of the nice question of the effect of a single even heavy dressing of manure, have still so much of agreement, as to give some confidence at least in the *direction*, and in any marked distinctions, which the mean results would indicate as between soil and soil.

It is seen that the subsoils contain from one-half to one-third only as much nitrogen as the surface soils. From this it is obvious that an inch or two of variation in depth, in sampling a surface soil, might make a comparatively important difference in the percentage of nitrogen obtained. The effect of the admixture of more or less of subsoil, in a sample of professedly surface soil, is seen in the difference between the mean percentage in the Rothamsted soil which had been cultivated on the Lois Weedon plan, and that of a similar description in the adjoining field, which had grown wheat for several successive years, but without its subsoil being disturbed. Thus the trenched plot at Rothamsted gives a mean percentage of only 0·1417 of nitrogen, whilst the plot in the adjoining field, notwithstanding it has grown wheat for many years successively without manure, gives 0·1523 per cent.

Before proceeding to compare with one another the Rothamsted and the Lois Weedon soils, we may here, in passing, call attention to the fact that, slight as they are, and whether accidental or not, the differences which the mean results would show between the plots devoted to the continuous growth of wheat at Rothamsted, under different conditions of manuring, are really, at least in direction, such as those manuring conditions would lead us to expect. Without laying too much stress on the actual figures, it is seen, then, that whilst the continuously unmanured plot gives 0·1523 per cent. of nitrogen, that which has received for a series of years mineral manure only (which would tend to the extraction of more nitrogen from the soil than where no manure was employed) gives 0·1459 per cent., or rather less than the former. The plot which has received annually ammoniacal salts (as the results showed somewhat in excess of the available minerals), indicates 0·1587 per cent. of nitrogen; or rather more than either the continuously unmanured or the continuously mineral-manured plot. And again, quite conformable with the above, the plot which has received continuously both mineral manure and an excess of ammoniacal salts, shows a slightly lower percentage (0·1556) than where the ammoniacal *salts* were employed without minerals; though with this excess of *ammoniacal* salts, a slightly higher one than the unmanured plot

Thus in both instances where a liberal supply of minerals has been used, the effect of which would be to use up, so to speak, more of the available nitrogen within the soil, the mean percentage of nitrogen indicated was rather lower than in the cases comparable with them on this point. It is freely granted, that some of the individual determinations are not quite consistent with the conditions here supposed; yet, with three or four experiments in each case, agreeing as most of them do pretty nearly, it is really of interest to observe, that the mean results appear to bear some relation to the known history of the plots.

Turning now to the Lois Weedon soils, it is seen that both specimens taken from the heavy-land field show a higher percentage of nitrogen than any of the Rothamsted plots, and particularly higher than the specially comparable instance at Rothamsted; namely, that where the land had been trenched and some of the subsoil intermixed with the surface soil. The Lois Weedon light land even, gives a slightly, but very slightly, higher percentage of nitrogen than the surface-soil of the continuously unmanured plot at Rothamsted. The difference, however, in favour of the Lois Weedon light land, notwithstanding it had been intermixed with subsoil and with marl, each containing only about half as much nitrogen, is more marked when it is compared with the trenched, that is, the Lois-Weedon-subsoiled plot at Rothamsted. To go to figures, we find that whilst the mean of four analyses gives for the Lois Weedon heavy-land *stubble* 0·1646 per cent. of nitrogen, the mean, also of four analyses, gives for the heavy-land *fallow* 0·2012 per cent. We cannot at all suppose that the whole of this large difference, amounting, as it would do, to from 1000 lbs. to 1500 lbs. per acre, if reckoned at about 1 foot deep, is due solely to the joint influence of the exhaustion of the just removed crop in the one case, and to the accumulation by the tilled bare fallow in the other; though it is obvious, that the effect of the accumulation by fallow would not extend uniformly to the depth of 1 foot; and consequently the assumption of a gain of 1000 lbs. or 1500 lbs. of nitrogen per acre is very much higher than the figures really imply, even supposing the samples were really taken to exactly corresponding depths in the two cases. The more probable supposition is, however, that the sample taken from the stubble did in fact represent a somewhat greater depth of the staple, or more of intermixed subsoil, than that taken from the fallow interval.

Turning for a moment to the subsoils and marl, the Rothamsted unexposed subsoil indicates a rather higher percentage of nitrogen than the Lois Weedon heavy-land subsoil—the former giving 0·0746 and the latter 0·0652 per cent. It is seen, on the other hand, that the subsoil and marl of the Lois Weedon light-

land field, with which the surface-soil is intermixed, both give a higher percentage than either the Rothamsted or the Lois Weedon heavy-land subsoil—that of the light-land subsoil being 0·0782, and that of the marl 0·0905 per cent. Lastly on this point, whilst the subsoil of the Lois Weedon heavy-land unmanured wheat-plot gives 0·0652 per cent., the subsoil of the plot devoted to rye-grass, with liquid manure, in the same field, gives 0·0790 per cent.

To resume—the comparison of the percentage of nitrogen in the Lois Weedon and the Rothamsted soils submitted to Mr. Smith's methods of growing wheat, the one with so much success, and the other with such signal failure, shows that the former contain a higher percentage of nitrogen than the latter. Thus, whilst the mean percentage in the trenched plot at Rothamsted is 0·1417, that in the light land at Lois Weedon is 0·1550 per cent., and in the heavy land at Lois Weedon (taking the mean of the eight determinations on both stubble and fallow plots) is 0·1827. Independently, then, of mere physical condition of soil, of mineral richness, or of other circumstances affecting the relations of the plant to the soil, we have here an intelligible chemical difference, perfectly consistent with what all other experience regarding the requirements for the vigorous growth of the wheat-crop would lead us to anticipate.

The questions still remain, however, whether the Lois Weedon soils, in all probability, have a greater power to acquire nitrogenous plant-food from atmospheric sources, or are likely more lightly to retain, or more easily to give up to the plant in an assimilable form, their previously existing or newly-accumulated stores of nitrogen?

With a view of getting such indications on these points as limited time would permit, the following experiments were made. Rather more than one thousand grains, in a finely-powdered state, of each of the soils enumerated in the Table (V.) given below (whose nitrogen had previously been determined), were put into a water-bath for about six hours, in order to secure an equal state of dryness. Exactly one thousand grains of each were then weighed, and respectively placed in small but equal-sized basins. Each of these was then mounted upon a small porcelain pot an inch and a half in height, and so placed in a large glass basin containing water to the depth of about an inch. The large basin was then covered with another such, and the whole left for three days at a temperature of 100° or more; by which from 1½ to nearly 4 per cent. only of water was absorbed by the different soils. The water in the large basin was then replaced by pretty strong ammonia-water; and the whole, covered as before, was *left for four* days in a warm room, the temperature being main-

TABLE V.—Results of Experiments on the Comparative Absorptive Power, for Water and Ammonia, of different Soils.

		Water, per cent.					Nitrogen per cent. in dry Soil.				Per cent. gain of Nitrogen by absorption.	
		After 3 days in closed moist warm atmosphere.	After 4 days' Ammonia-water vapour at 70°.	Added Nov. 26.	Added Nov. 30.	Retained after 18 hours' exposure at 70°.	After absorption of Ammonia. Experiment 1.	After absorption of Ammonia. Experiment 2.	After absorption of Ammonia. Mean.	Before absorption of Ammonia. Mean.	On Dry Soil.	On previously existing Nitrogen.
Rotham-sted Soil	Continuously unmanured	1·80	2·78	5·0	10·0	1·65	0·2880	0·2779	0·2829	0·1523	0·1306	85·7
Lois Weedon Soil	Heavy Land	2·53	3·35	5·0	10·0	2·48	0·3970	0·3905	0·3937	0·2012	0·1925	95·7
	Light Land	1·41	2·35			1·60	0·2547	0·2529	0·2538	0·1550	0·0988	63·7
	Heavy Land Subsoil	3·88	4·95			2·51	0·2930	0·2959	0·2944	0·0652	0·2292	351·5
	Light Land Subsoil	2·00	2·80			1·57	0·1870	0·1912	0·1891	0·0782	0·1109	141·8

tained at about 70°. Even now none of the soils had gaine quite 5 per cent. of water; and as it was thought that the absorp tion of ammonia would be facilitated thereby, 5 per cent. wa now added to each of them; and after another four days' expo sure to the moist ammoniacal atmosphere, a further 10 per cen of water was added. In four days more the little basins wer removed from the ammoniacal atmosphere, and by this time th soils smelt very strongly of ammonia. In order to expel a that was not retained in a comparatively stable condition, th little basins and their contents, uncovered, were exposed fo eighteen hours in the warm room at about 70°; by which, as wil be seen in the Table, the amount of moisture was reduced i all cases to below 3, and in some to below 2 per cent. In thi state the percentage of nitrogen was again determined in th soils by the soda-lime and platinum-salt process; and in th Table are given the results of these determinations; and by the side, the mean percentage of nitrogen in the respective soi *before* they were submitted to the ammoniacal vapours. Th percentages of water in the specimens at the different stages, above described, and the percentage *gain* of nitrogen by absor tion, calculated both upon the dry soils and upon the previous existing nitrogen in them, are also given; the former to the le and the latter to the right of the nitrogen determinations.

A glance at the Table shows that there is some general thou not numerically exact connexion between the capacity of t different soils for the absorption and retention of water on t one hand, and of ammonia on the other. It is seen that the L Weedon heavy land and its subsoil absorbed and retained a ve much larger proportion both of water and ammonia than eitl the Rothamsted soil, or the Lois Weedon light land, or ligl land subsoil. Thus the nitrogen in the Lois Weedon hea land, which was before the highest in the series, has been rais by the absorption experiment by 0·1925 per cent.; whilst that the Rothamsted soil is raised by only 0·1306. The Lois Weed light land has, however, absorbed, or at least retained, less ammonia than the Rothamsted soil, the increased amount nitrogen in its case being 0·0988 per cent. It is further se that both of the Lois Weedon subsoils have absorbed more th their corresponding surface soils; the increased percentage nitrogen by absorption of ammonia being in the heavy-land su soil 0·2292, and in the light-land subsoil 0·1109 per cent.

It was our intention, had time permitted, to have complet other experiments of this kind for the purposes of this pap and we may possibly yet be able before concluding to appe the results of some such which are now in progress. In def *of these*, however, we cannot fail to observe as a significant fa

that the Lois Weedon heavy land, which has yielded Mr. Smith his best results, both contained more nitrogen in its original state, and absorbed and retained, under equal circumstances, both more water and more ammonia than the Rothamsted soil. The Lois Weedon light land, however, although containing slightly more nitrogen in its natural state than the soil at Rothamsted, absorbed and retained, in the experiment above described, rather less both of water and of ammonia than the Rothamsted soil. In drawing any conclusion from the results of an experiment of this kind, in regard to the probable comparative qualities of the soils in their natural state and position, we must first carefully consider what are the circumstances, in a necessarily artificial experiment, which might vitiate a strict comparison of the figures. It is to be borne in mind then, that the soils, when submitted to the absorption experiments, were in an equally finely divided state, and they would, therefore, expose nearly equal surfaces to the watery and ammoniacal vapours. The results should, therefore, show the comparative absorptive powers of equal surfaces of the respective soils. And this being so, of the three surface soils the Lois Weedon heavy land has the highest, the Rothamsted soil the next, and the Lois Weedon light land the least absorbent power in relation to a given surface exposed. But in its natural state and position the Lois Weedon light land would undoubtedly expose a much greater surface of atmospheric influences than the Rothamsted soil. Hence probably the reason that the Lois Weedon light land, though it did not absorb more ammonia in the experiment cited, yet in its natural state contained a higher percentage of nitrogen than the Rothamsted soil. Hence probably also, this Lois Weedon light land would both absorb or otherwise accumulate more nitrogen in an available form, under equal climatic circumstances, and yield it up more readily to the plant, than the soil at Rothamsted.

Since the above was in type, the additional experiments referred to have been concluded, and we give here a short statement of the results. In this second series of absorption experiments, the object was to include the surface and subsoil of the land devoted to the Lois Weedon experiments at Rothamsted; and also to submit the soils in a rather moister state to the ammoniacal vapours. 800 grains, in an equal state of dryness, of each of the soils enumerated in the Table below, had 25 septems, or about 23 per cent., of water added to them. In this state they were submitted, in the same manner as in the previous experiment, to moist ammoniacal vapours at a temperature of about 70°; though in this case for only 3 days instead of 12 as formerly. At the conclusion of the absorption *period* each little basin of soil was

exposed for 24 hours in the open warm room at 60° to 70°. In this condition the specimens were put into closed bottles; from each of which one portion was taken for the determination of the moisture separable at 212°, and separate portions for that of the nitrogen, the duplicate being in each case made by a second experimenter. The following are the results:—

TABLE VI.—Results of further Experiments on the comparative Absorptive Power, for Water and Ammonia, of different Soils.

Description of the Soils.		Per cent. Water retained after absorption and 24 hours' exposure at 70°.	Nitrogen per cent. in dry Soil.				Per cent. gain of Nitrogen by absorption.	
			After absorption of Ammonia.			Before absorption of Ammonia. — Mean.	On dry Soil.	On previously existing Nitrogen.
			Experiment 1.	Experiment 2.	Mean.			
Rothamsted Soils ..	Continuously unmanured	5·33	0·2498	0·2632	0·2565	0·1523	·1042	68·4
	Lois-Weedon-Plot Surface Soil ..	5·19	0·2525	0·2462	0·2493	0·1417	0·1076	75·9
	Lois-Weedon-Plot Subsoil	5·45	0·2378	0·2239	0·2308	0·0746	0·1562	209·4
Lois Weedon Soils ..	Heavy Land Surface Soil	5·65	0·3445	0·3308	0·3376	0·2012	0·1364	67·8
	Light Land Surface Soil	4·69	0·2488	0·2425	0·2456	0·1550	0·0906	58·4

The soils being throughout this experiment in a moister state, it seems they did not become so dry by exposure in the warm room; nor were the differences in the retentive power under these circumstances so great as in the former instance. Nevertheless, conformably with the former results, the Lois Weedon heavy land retained more water than the light land, and more also than either of the Rothamsted soils. The Rothamsted subsoil, too, retains more than either of the Rothamsted surface soils, though the surface soil that had been trenched does not bear the same relation to the one which had not, in regard to retention of water, as might be expected, though we shall find it does so in regard to that of ammonia.

With regard to the absorption and retention of ammonia, the results of this second series of experiments are entirely consistent with those of the first. They may indeed be considered to be the more so, from the variation in the actual per cent. of absorption, since the circumstances of the two sets of experiments equally varied. We find, as before, that the Lois Weedon heavy land absorbed and retained more ammonia than the Rothamsted soils, and the latter more than the Lois Weedon light land. And, as was the case with the Lois Weedon soils and

their respective subsoils, the Rothamsted subsoil absorbed and retained more ammonia than its surface soil; and conformably with the greater power in this respect of the subsoil, we find the trenched land at Rothamsted absorbed and retained rather more ammonia than the one which had not had any of its subsoil intermixed with it.

In fact the results of this second series of absorption experiments confirm so entirely the bearings of the former one on all essential points, that the arguments and conclusions already recorded do not require any modification or correction from this additional evidence.

The result of the comparative examination in the laboratory of the Lois Weedon and the Rothamsted soils clearly brings out the fact, that of the former, the heavy one at least, both contained more nitrogen in some form, and had the power of absorbing more ammonia under equal circumstances, than the latter; whilst the experiments in the field have shown, that a much greater porosity, and consequently a greater amount of surface for atmospheric influences, is attained in this more highly nitrogenous, and more powerfully absorbent heavy soil at Lois Weedon, than, by an equal expenditure of mechanical means, could be attained in the one at Rothamsted. The Lois Weedon light land too, certainly contained more nitrogen than the Rothamsted soil in its natural state; and, as we have seen, would in that same state, in all probability, acquire more under equal climatic circumstances, and yield up more in a given time to the growing crop.

It would be taking a very narrow view of the case to suppose, that no other circumstances than an increased supply of nitrogen within the soil have had their share in the success of the wheat crop at Lois Weedon. There is no doubt that the methods there adopted are well fitted to develop to the highest degree the healthy distribution of both the underground and above-ground feeders of the plant. Those methods favour also the liberation, the elaboration, and the distribution throughout the root-searching area of the plant, of the mineral food of the crop, in a manner that it would be impossible to emulate in the application of direct manures. This system moreover, independently of the mere *amount* of available nitrogen provided within the soil by its means, secures also, better than any other means could do, the perfect distribution of the assimilable nitrogenous, wherever there is a liberal supply of the assimilable mineral food. It so happens too, that it is just those soils which are known to possess generally the greatest absorptive and retentive powers, that have generally also the *greatest* stores of most of the necessary

mineral constituents of our crops. It is not, however, all whi[illegible] possess these physical or chemical powers of surface, and these [illegible] herent mineral riches, that will allow, with equal ease, the ex[illegible] sure of an equal surface for the development and availa[illegible] activity of these powers and stores.

That the nitrogen shown to exist in soils by the methods of a[illegible] lysis which have generally been adopted, does not necessarily [illegible] exist in a form readily and within a limited period assimilable [illegible] plants, is easily demonstrable. Thus, with a view to this poi[illegible] several of the soils which have been the subject of this paper w[illegible] operated upon as follows. A given weight (100 grains) was [illegible] into a flask, 20 ounces of water added, and a little strong cau[illegible] potash ley. The flask was then connected by a tube wit[illegible] Liebig's condenser, and heat applied so as to keep the mixt[illegible] gently boiling. A series of smaller flasks, gauged and mar[illegible] to hold exactly 4 ounces each, were then successively attache[illegible] receivers, until three separate fifths of the original bulk of fl[illegible] had been collected. It has been shown by Boussingault, that when very dilute solutions of ammonia or ammoniacal salt are distilled in this way, practically the whole of the ammonia will come over in the first two-fifths of the distillate. And it is obvious that boiling a soil in a fine state of division with dilute caustic potash for two or three hours, would liberate a very much larger proportion of its nitrogen in the form of ammonia than could be rendered soluble and available for plants in many years of the influence of air and moisture upon a soil in the very limited state of division in which it exists in cultivated land. Collecting, however, a distillate of three separate fifths, supersaturating each with a known quantity of a test acid, adding litmus, and then neutralising by a test alkaline solution, it was found that only a small proportion of the nitrogen existing in the soil (the quantity varying slightly with the rapidity of the distillation) was obtained in the distillates. And quite conformably with the point established by Boussingault, and confirmed in our own experiments in the case of rain-waters, the first fifth contained by far the larger proportion of the whole ammonia which came over; the third fifth, in fact, containing very little. It was, however, found, that a very much larger proportion of the total nitrogen distilled over as ammonia from the soils after they had been submitted to ammoniacal vapours as above described, than before they had been so treated.

Although, therefore, it may generally happen that a soil which contains the highest per cent. of nitrogen may have a greater aptitude, if well worked, both to acquire more and to yield up its accumulated stores, and hence, so far be more fertile, yet it is *obviously* quite inadmissible to suppose, that the addition of a com-

paratively small amount of nitrogen to the soil, in a form proved to be readily accessible, can be of no avail, simply because the soil itself already contains a much larger absolute amount;—though, from its distribution and state of combination, it may be but in very small proportion available within a single season. That soils are not *necessarily* more fertile because they contain a larger actual amount of nitrogen, is interestingly illustrated in the effects of burning clays. The burnt clay after some exposure, as has been shown by Professor Voelcker, contains a much less percentage of nitrogen than the unburnt. No doubt the increased supply of available mineral food, as well as the change of texture by which the roots of the plant, as well as the atmosphere, are enabled better to permeate the soil, have much to do with the result. That this is so, may indeed be judged, by a consideration of the descriptions of crop grown with most advantage after the burning process. There can be little doubt, however, that the smaller amount of combined nitrogen, newly acquired by the porous burnt soil, will be much more accessible to the plant than the larger amount locked up in the unburnt clay; and to this circumstance, in all probability, a fair share of the beneficial effects of burning should be attributed. In fact, this smaller amount of accessible nitrogen in the exposed burnt clay, has a much greater proportional effect as compared with that in the unburnt, just as the smaller amount added in manure in an available form has a striking effect in an ordinary soil, notwithstanding that the latter may contain an enormously larger amount, but in a less accessible condition.

It is further, we think, very doubtful whether ordinary *agriculturally* cultivated soils, even *contain*, in any form, so large an amount of nitrogen as the uncritical reader might be led to suppose from the statements on this point given by Baron Liebig in the last number of this Journal. The percentages given in soils by Dr. Krocker, whose figures Baron Liebig does not quote in the Paper referred to, agree very closely in range with our own experience in such matters.* Of those which he has now brought more prominently forward, and which we have quoted in full at an earlier page, the range is in some cases so high, and the discrepancies between the individual analyses of the same soil, as already shown, so great, that we are disposed to place much more confidence in the medium amounts given in that Table. Then, again, neither the Russian black earth, nor the soils of gardens or woods (the latter being the only ones given by

* Dr. Krocker's results will be found in the Appendix to Baron Liebig's 4th English Edition of his *Chemistry in its Applications to Agriculture and Physiology*, p. 275.

Baron Liebig as analysed by himself), can be taken as parallel with ordinary farming-land, under ordinary cultivation.

With regard to any estimates that might be made from our own determinations of nitrogen in the soils at Rothamsted and Lois Weedon, of the probable acreage amount within a given depth, it may be observed, that the result obtained and published ten years ago of the amount of nitrogen in the soil of our continuously unmanured wheat plot (0·2 p. c.), was considerably higher than that now recorded in Table IV. This was to a great extent due to the fact, that the earlier sample was taken to little more than half the depth of the recent one. By reference to the analysis book we also find that, for a substance containing so small an amount of nitrogen, much too small a quantity was submitted to analysis. There is also the consideration, whether or not part of the difference is due to the reduction of the condition of the land in regard to nitrogen, by the removal of ten more unmanured wheat crops. It is clear, however, that the determination of nitrogen made upon a sample taken to only half that depth, cannot be taken in estimating the probable acreage amount to the depth of one foot. Then, again, since the analyses now recorded were made upon samples taken to the depth of only nine inches, the calculated acreage amounts one foot deep, given in the lower part of Table IV. for comparison with Baron Liebig's adopted depth of one foot, must obviously be too high. With these explanations, then, as to the degree of applicability of our figures to any estimates of acreage amounts, the results are committed to the reader, as some additional data on the many points of interest which this question of the nitrogen in soils involves.

It was our hope and intention, had our time permitted it, to have included within the limits of this paper a short review of existing knowledge, and especially of the results and tendency of the investigations of recent times, bearing upon the sources of available nitrogen to cultivated plants, both within and without the soil. It is, indeed, remarkable how many are the independent researches, from experimenters both numerous and varied in their pursuit and object, which have come in upon this field of inquiry during the last few years. It is not less remarkable, that the subject of agricultural chemistry, perhaps more than any other, has demanded and successfully incited a rigid investigation of *methods* of research; and it has, both in this country, in Germany, and in France, led to improvement, and a much greater degree of accuracy, in some of the most difficult departments of chemical analysis. Besides the establishment of methods for the determination of quantities of ammonia and nitric acid, formerly far too minute to be made the subject of *successful* quantitative estimation, the analysis of gases, the

peculiar influences of the sun's rays, meteorological phenomena generally, vegetable physiology in its various departments, structural and functional, not a little aided by the revelations of the microscope, are all now receiving their special study, and will find their special application in the elucidation of important agricultural questions. And, although we cannot fail to see that all will, sooner or later, conspire to give security to the next important step in these inquiries, it must be freely admitted, that as yet the difference of opinion is so great, and there really are so many points undetermined, that we may rest satisfied to delay for the present the summary we had intended to give, in the hope that, when the opportunity next occurs, we may have a less questioned advance to record.

In conclusion, the field results recorded in the foregoing pages have clearly shown that, from some cause or other, the endeavour, by given mechanical operations, to attain a deep and porous staple, with the admixture with the surface of a certain portion of the subsoil, was quite insufficient to secure in the Rothamsted soil, those conditions of texture and of other qualities incident to it, essential to the successful start, and healthy after development, especially of an early thinly-seeded wheat crop. The field experiments also afford conclusive evidence, that the defect, so far as it was chemical, was not connected with a deficiency of available mineral, relatively to available nitrogenous food. The concluding experiments showed, on the contrary, that an increased provision of nitrogen in the soil, by manure, gave a very much larger amount of increase on the now more thickly-seeded land, than an increased supply of the mineral constituents of the crop could do. That such should be the result on the land at Rothamsted, where the Lois Weedon plan had failed, was perfectly consistent with the limited degree of porosity for the exposure of surface to atmospheric influences, and for the permeation of the roots, which had been attained by the means employed. It is also perfectly consistent with those views as to the sources of the resultant effects of fallow, and as to the characteristic action of different constituents of manure on ordinarily cultivated land, upon which we have so often insisted.

The results in the laboratory again, have borne their consistent evidence on every point. Thus, bearing in mind at the same time the comparative character as to porosity of the Lois Weedon and the Rothamsted soils, it is found that, taking a given amount of each in its natural state, both of these more porous soils at Lois Weedon *contain* more nitrogen than those at Rothamsted. One of them again has, besides its greater exposed surface in the field, no doubt associated *with* a greater susceptibility to atmos-

pheric influences generally, a greater power of absorption for ammonia in relation to a given surface. The other of these Lois Weedon soils, although absorbing a less amount of ammonia in relation to a given weight having an equal surface exposed, undoubtedly offers, under equal circumstances in the field, a much larger amount of surface for absorption than the soils at Rothamsted. Indeed, we can have little doubt, that to the difference between the respective soils in the degree of the conjoint influences of mechanical division, and of power of absorption and liberation (in part depending on it) of a sufficiency of available nitrogen relatively to the available mineral constituents, must in great measure be attributed the difference in the results obtained at Lois Weedon and at Rothamsted.

Further, in the results which have been recorded, whether in the field or in the laboratory, we find additional confirmation of the view:—

"That the chemical effects of *fallow*, in increasing the growth of the cereal grains, are not measurable by the amount of the additional mineral food of plants liberated thereby; these being, under ordinary cultivation, in excess of the assimilable nitrogen existing in, or condensed within, the soil in the same period of time. The amount of the latter, therefore—(*i. e.*) the *available nitrogen*—is the measure of the increased produce of grain which will be obtained."

But the system adopted by the Rev. Mr. Smith, of growing wheat year after year on alternate strips of the same land, and as a general rule without any restoration, directly or indirectly, of the mineral constituents removed in the crops, certainly does not come within the definition of "*ordinary cultivation*," as referred to in the paragraph just quoted. Whilst, therefore, a soil not only rich in the absolute amount of the mineral constituents of the crop, but one capable of sufficient mechanical division, and susceptible to the liberating action of atmospheric influences, is absolutely essential to the success of the plan, yet all experience, practical and experimental, tends to show, that a large amount of inherent mineral stores, and their easy liberation, or available form for the use of the plant, will only suffice for the production of full crops of wheat, provided there be at the same time a liberal supply of *available* nitrogen *within the soil itself*.

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ON SOME POINTS

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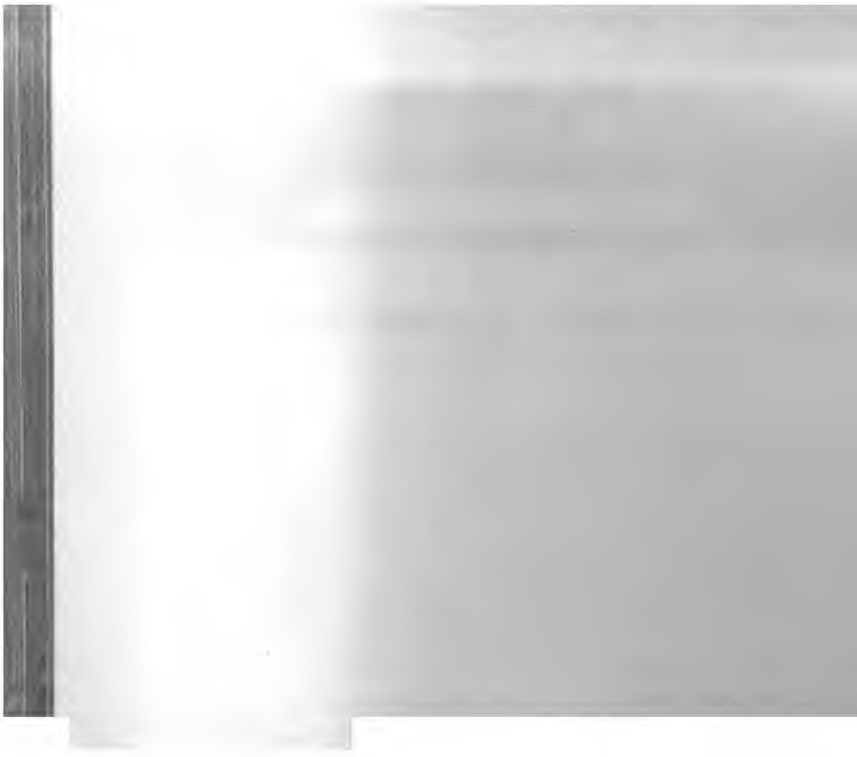
COMPOSITION OF WHEAT-GRAIN, ITS PRODUCTS IN THE MILL, AND BREAD.

BY

J. B. LAWES, F.R.S., F.C.S., AND J. H. GILBERT, PH.D., F.C.S.

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POSITION OF WHEAT-GRAIN, ITS PRODUCTS IN THE MILL AND BREAD.

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composition of the grain yielding the most important article man food in temperate climates, its yield of valuable products, the varying composition either of the grain itself, or of these ıcts, according to the conditions of growth, or the circumes of after preparation, are subjects worthy the attention ly of states and of men of science. Accordingly, we find that mical examination of wheat-grain and its products, has from to time been undertaken by chemists of repute; sometimes natter of private investigation, and at others of public inquiry; almost as numerous as the names of the experimenters, are pecial lines of research which they have selected.

Ve are indebted to Beccaria for the first notice, more than ıtury ago, of the gluten in wheat. Among the earlier investi-s of the subsequent period, are, Proust, Vauquelin, Saussure and Vogel, who have examined the proximate ciples, and some of the changes to which they are subject, in ous descriptions of wheat, of flour, or of bread. M. Bousgault has somewhat elaborately studied various branches of subject more recently; and we are indebted to Dumas,

Payen, Johnston, and Dr. R. D. Thomson for original a[illegible] well as a considerable amount of collected information. The mo[illegible] t recent, on some points the most detailed, and from advance i[illegible] methods, perhaps on some also the most reliable, are the result [illegible] of M. Peligot in 1849, on the proximate constitution of variou[illegible] kinds of wheat, and of M. Millon in 1849 and 1854, on some[illegible] what similar points. Lastly, in 1853 M. Poggiale, and in 185[illegible] Dr. Maclagan, have given the results of their investigations o[illegible] the characters and composition of bread.

Besides these more general investigations, we have had i[illegible] recent times many special inquiries connected with our subjec[illegible]. Thus, M. Boussingault has given us analyses of the ashes [illegible] f wheat; and many other such analyses have been made in Ge[illegible] many, and elsewhere, since the first appearance, in 1840, of Baro[illegible] Liebig's work on "Chemistry in its Applications to Agricultu[illegible] e and Physiology." In this country, Mr. Way has given us th[illegible] e most extensive series of wheat-grain-ash analyses, his list includin[illegible] g those of 26 specimens or descriptions.

The plan of our own investigation, which unfortunately ha[illegible] s been much less perfectly filled up than we at first intended, wa[illegible] s entered upon more than a dozen years ago, and was devised wit[illegible] h reference to the following points:—

1st. The influence of varying characters of season, and of vari-ous manuring, upon the organic and mineral composition of wheat grain.

2ndly. The characters of varieties, especially in relation to their adaptation, and the qualities they then develop, under the influence of broader distinctions as to locality, altitude, latitude, and vary-ing climatic circumstances generally.

It is in the second branch of the inquiry that we have fallen the furthest short of our intentions. With a view to its prosecution, a journey through the chief corn growing districts of Europe, com-mencing at the northernmost point at which wheat is grown suc-cessfully, was about to be undertaken in 1848; but the social dis-turbances on the continent at that period, necessarily prevented it. The plan proposed was—to collect information, as to the geological and meteorological characters of the various localities, as to the mode of culture, and as to the general acreage yield, both in straw and grain; and lastly, to procure characteristic specimens for chemical examination at home. Failing entirely in the execution of this *design*, the Exhibition of 1851 was looked forward to as an oppor-

for procuring specimens not only of wheat, but of other
ble products, and perhaps also important particulars of their
ı, from various countries and climates. Such, however, was
ision of authority, and such the alleged preference given to
institutions in such matters, that, whether the latter bene-
r not, the collection which we, as private individuals, were
l to make, was entirely inadequate to our object. From
lifficulties it is, that our second main object of inquiry was
ırily to a great extent abandoned; and chiefly for this rea-
ıt partly owing to the pressure of other subjects, the first
e limited or local branch of the investigation has in recent
been but imperfectly followed up. And, as it is probable
must for some time remain so, it has been thought desirable
› put on record the results already obtained; hoping that
ıay serve the double purpose, of confirming or adding to
ısly existing knowledge, and of indicating to others the
most requiring further study.

ə following is a brief outline of the plan of investigation
has yielded the results which we have now to lay before the
r.

›m the season 1843–4, up to the present time, wheat has
growing in the same field continuously, both without
e, by ordinary, and by various chemical manures. As a
l rule, the same description of manure has succeeded year
ear on the same plot of land. The amount of produce, grain,
and chaff, and its characters as to weight per bushel, &c.,
n every case, been carefully ascertained and recorded.
es from each plot—both grain and straw—have also been
ed every year. Of each of these samples two weighed por-
re coarsely ground; the *dry matter* determined at a tempera-
f 212°; and the *ash* by burning on sheets of platinum, in
›n muffles arranged for that purpose.* Other weighed por-
f grain and straw are partially dried, so as to prevent their
position; and in this state they are preserved for any exami-
of their organic constituents. By this course of procedure,
mass of results has been obtained, illustrating the influence
ıon and manuring, upon the percentage of dry substance,
mineral constituents, in the produce. In selected cases,
trogen in the grain, and in the straw, has been determined.

* The dry matter and ash, were not determined in such complete series in the earlier years, as in the later.

A summary table of these dry matter, ash, and nitrogen results, will be given below. In from twenty to thirty cases complete analyses of the grain-ashes have been made, and the results of these will be given in full.

Besides the experiments above described, in selected cases chiefly from the produce of the earlier years of the field experiments, it was sought to ascertain the comparative *yield of flour*, and also the characters of the flour, of grain grown by different manures in the same season, or by the produce of different seasons. The *colonist's steel handmill* was first had recourse to for this purpose. But it was soon found, that it was extremely difficult so to regulate the machine, as to secure uniform action upon the different grains; and it was further found, that the grain, and especially the bran, was cut up rather than crushed, so as to leave too much of flour in the portion separated as bran, and too much of bran in that separated as flour; and hence the results were not sufficiently comparable with those of the ordinary mill. Arrangements were therefore made for prosecuting the inquiry at a flour mill in the neighbourhood, worked by water power. Weighed quantities of the selected samples (from 125 to 250 lbs. each), were passed through the stones, and the "*meal*" thus obtained, through the dressing machine, under our own personal superintendence; great care being taken to clear from the different parts of the apparatus the whole of one lot, before another was commenced upon.

The yield in the dressing machine of each of the different products was ascertained, and its percentage in relation to the total grain or its "meal," has been calculated. Portions of each of these products have had their dry matter (at 212°), and their mineral matter (by burning on platinum), determined. The percentage of nitrogen in a few selected series—from the finest flour down to the coarsest bran—has also been estimated; and in the same cases, the amounts of one or two of the more important constituents of the ash have also been determined. The results of these dry matter, ash, nitrogen, and constituent of ash, determinations, in the series of different products obtained in the mill, will be given in tables further on.

The original design, was to complete the examination of the mill products, by determining in several series of them, the percentage of each of their proximate organic principles; and also *the amount* and composition of mineral matters, associated with

ı respectively. It was hoped, by this latter inquiry, to obtain ortant collateral information, bearing upon the influence of ous constituents upon the healthy and special development of plant. Although, however, specimens of the flour are pre- d for this purpose, as well as the ashes of each crude pro- , it is feared that this subject cannot be proceeded with, at for a considerable time to come.

Portions of the different products of the dressing machine uding more or less of the finest flour, of the more granular, f the more branny particles respectively), from grains of what various history of growth, have been experimented to ascertain their comparative bread-making qualities; and results, together with a few examinations of baker's bread, a discussion of the results of other experimenters, as to the of bread from a given amount of flour, and the percentage ter and of nitrogen in the former, will be given below.

With this short outline of the plan of investigation which een pursued, we proceed now to a discussion of the results h have been obtained.

In Table I are given, in the first four columns, certain pro- nt characters of the produce of each of ten years of the suc- ve growth of wheat as above described. The items are:—

The total produce per acre (grain and straw), in lbs.;
The per cent. of grain in the total produce;
The per cent. of dressed grain in the total grain; and,
The weight per bushel of dressed grain in lbs.

The figure given for each year, generally represents the age of about 40 cases; and the characters enumerated are best which can be given in a summary and numerical form, indicate the more or less favourable condition of the respec- seasons for the healthy development of the crop, and the ect maturation of the grain.

In the second set of three columns are given, side by side the general characters just described, the percentages in grain of each year—

Of dry substance;
Of ash in dry substance; and,
Of nitrogen in dry substance;

two former items being in most cases the average of 30 to cases in each *year; but the* per cent. of *nitrogen*, is in each *ance, the mean of a few* selected cases only.

In the third set of three columns, are given similar particulars relating to the composition of the straw. The percentages of dry substance and of ash in the straw are, however, not the averages of so many cases in each year, as are those for the grain and the determinations of nitrogen in the straw, have also been made in fewer cases than in the grain.

It will thus be seen, that the table affords a summary view of a really enormous amount of experimental result, and we ought to be able by its means to discover, at least the broad and characteristic effects of varying seasons, upon the composition of the crop.* This indeed is all we could hope to attain in such a mere outline and general treatment of the subject as is appropriate to our present purpose.

TABLE I.

General Summary.

Harvest	Particulars of the Produce.				Composition of Grain.			Composition of Straw.		
	Total grain & straw per acre in lbs.	Percent. grain in total produce.	Percent. dressed grain in total grain.	Weight per bushel of dressed grain in lbs.	Percent. dry (212°.)	Percent. ash in dry.	Percent. nitrogen in dry.	Percent. dry (212°.)	Percent. ash in dry.	Percent. nitrogen in dry.
1845	5545	33·1	90·1	56·7	80·8	1·91	2·25	...	7·06	0·92
1846	4114	43·1	93·2	63·1	84·3	1·96	2·15	...	6 02	0·67
1847	5221	36·4	93·6	62·0	...	...	2·30	...	5·56	0 73
1848	4517	36·7	89·0	58·5	80·3	2·02	2·39	...	7·24	0·74
1849	5321	40·9	95·5	63·5	83·1	1·84	1·94	82·6	6·17	0·82
1850	5496	33·6	94·3	60·9	84 4	1·99	2·15	84·4	5·88	0 87
1851	5279	38·2	92·1	62·6	84·2	1·89	1·98	84·7	5·88	0·78
1852	4299	31·6	92·1	56·7	83·2	2·00	2·38	82·6	6 53	0·79
1853	3932	25 1	85·9	50·2	80·8	2·24	2·35	81·0	6·27	1 20
1854	6803	35·8	95·6	61·4	84·9	1·93	2·14	83 7	5·08	0·69
Means	5053	35·4	92·1	59·6	82·9	1·98	2·20	83 2	6·17	0·82

Leaving then out of view all minor points, and confining ourselves to our already defined object—namely, that of ascertaining the general direction of the influence of variation of season upon the composition of the wheat crop—we cannot fail to see, that wherever the three items indicating the *quality* of the produce

* It should be stated, that up to 1848 inclusive, the description of wheat was the Old Red Lammas; from 1849 to 1852 inclusive, it was the Red Cluster, and since that time the Rostock. The variations, according to season, both in the characters and *composition* of the produce, are, however, very marked within the period of growth *of each separate* description.

edly distinguish the crop as favourably developed, we have
ieral tendency to a high percentage of dry substance, and to
percentage both of mineral matter, and of nitrogen, in that
ubstance. This generalization is more especially applicable
e grain; but with some exceptions, mostly explicable on a
ed consideration of the circumstances and degree of its deve-
nt, it applies to a great extent to the straw also.

et us take in illustration the extreme cases in the Table. The
is of 1846, 1849, and 1851, with in the cases of the twc
large produce also, give us the best proportion of grain in
produce, more than the average proportion of dressed grain in
grain, and the highest weight per bushel—a very significant
cter. With this cumulative evidence as to the relatively
rable development and maturation of these crops, we find the
in two of the cases, to be among the highest in percentage
y matter; and in the third (1849), though not so high as we
d have expected, it is still above the average. The per-
ges of mineral matter and of nitrogen in the dry substance of
rain, are at the same time, in these three cases, the lowest in
eries. The seasons of 1850 and 1854 again, with large
nts of produce, yielded also very fairly developed grain; and
idently they afford a high percentage of dry substance, and
percentages both of mineral matter, and of nitrogen, in that
ubstance, than the cases of obviously inferior maturation.
some exceptions, it will be seen, that the straws also of these
etter years, give a tendency to low percentages both of mineral
r and of nitrogen in their dry substance.

urning now to the converse aspect, the season of 1853, shows
in the general characters of the produce, to have been in
respect the least favourable to the crop; and it should be
l that in this instance (as well as in 1845 to which we shall
refer), the seed was not sown until the spring. In 1853 the
ice of grain was small as well as very bad in quality; and
these characters, we have in the grain nearly the lowest per-
ge of dry matter, and the highest percentage of ash and of
gen in that dry matter. In the straw, too, the dry matter is
the ash somewhat high, and the nitrogen much the highest
e series. In 1845, another year of spring-sowing, and at the
time of very bad quality of produce, we have nevertheless a
amount of growth; a fact which tends to explain some of the
rences in composition as compared with 1853. Thus, 1845

gives us low percentage of dry matter, but not very high, either ash or nitrogen, in the grain. The straw, however, gives high percentages both of ash and of nitrogen; it being in the latter point next in order to 1853. The seasons of 1848 and 1852 again show low characters of produce. The former has coincidently the lowest percentage of dry matter in the grain in the series; and both have high percentage of ash and nitrogen in the dry substance of the grain. In the straw, the ash is in 1848 the highest, and in 1852 above the average; the nitrogen in dry matter of straw being however in neither instance high.

In several of the cases here cited, there are deviations from our general assumption on one point or other. But an examination in greater detail, would in most or all of them clear up the apparent discrepancy. When indeed, we bear in mind how infinitely varied was the mutual adaptation of climatic circumstances to stage of growth of the plant, in almost every case, it would indeed be anomalous, did we not find a corresponding variation on some point or other, in the characters or composition of the crop. Still, we have the fact broadly marked, that within the range of our own locality and climate, high maturation of the wheat crop is, other things being equal, generally associated with a high percentage of dry substance, and a low percentage of both mineral and nitrogenous constituents. Were we, however, extending the period of our review, and going into detail as to varying climatic circumstances, interesting exceptions could be pointed out.

It may be observed in passing, that owing to the general relationships of the amounts of grain to straw, and the generally coincident variations in the percentages of nitrogen in each, the tendency of all these variations is in a degree so to neutralize each other, as to give a comparatively limited range of difference in the figures, representing for each year, the percentage of nitrogen in the dry substance of the total produce—grain and straw together.

The tendency of maturation, to reduce the percentages mineral matter, and frequently of nitrogen also, is not observable in corn crops alone. We have fully illustrated it in the case of the turnip; and our unpublished evidence in regard to some other crops, goes in the same direction. The fact is indeed very important to bear in mind; for it constitutes an important item in our study of the variations which are found to exist in the composition both of the organic substance, and of the ash, of one and the same crop grown under different circumstances. We may particularly observe

that the obvious reduction in the percentage of nitrogen in wheat-grain, the more, within certain climatic limits, the seed is perfected, is in itself a fact of the highest interest; and it is the more so, when we consider how exceedingly dependent for full growth, is this crop upon a liberal supply of available nitrogen within the soil.

Bearing in mind, then, the general points of relationship which have been established between the characters of the crop as to development and maturation on the one hand, and the percentage amounts of certain constituents on the other, let us now see—what is the general influence of characteristic constituents of *manure*, upon the characters and composition of our wheat crop, which is allowed to remain on the land until the plant has fulfilled its highest function—namely, that of producing a ripened seed?

In illustration of this point we have arranged in Table III, the same particulars as to general character of the crop, and as to the composition of the produce, from several individual plots during the ten years; instead of the average of the series in each year, as in Table I. The cases selected for the comparison are:—

1. A continuously unmanured plot;
2. A plot having an excess of ammonia-salts alone every year;
3. The average of several plots, each having the same amount of ammonia-salts as the plot just mentioned, but with it, a more or less perfect provision by manure, of the *mineral constituents* also.

It would be impossible to give the detail supplying all the results collected in this Table III; but perhaps it is only proper that we should do so, so far at least as the percentage of nitrogen in the dry substance of the grain is concerned.

TABLE II.

Determinations of Nitrogen per Cent. in the Dry Matter of Wheat Grain grown at Rothamsted.

Harvests.	Experiments. 1	2	3	4	5	Mean.
Unmanured.						
1845	2·28	2·21	2·33	2·30	...	2·28
1846	2·11	2·12	...	...	...	2·11
1847	2·11	2·08	2·22	2·22	...	2·16
1848	2·33	2·34	2·32	2·37	...	2·34
1849	1·85	1·83	1·91	...	...	1·86
1850	2·07	...	2·10	2·07	...	2·08
1851	1·80	1·74	1·89	1·76	...	1·80
1852	2·31	2·23	2·38	2·31	...	2·31
1853	2·26	...	2·33	2·38	...	2·32
1854	2·06	2·06	1·98	1·96	...	2·02
Manured with Ammonia-Salts only.						
1845	2·18	2·29	2·22	2·23	...	2·23
1846	2·18	2·12	2·29	2·19	...	2·19
1847	2·35	2·29	2·42	2·32	...	2·34
1848	2·39	2·41	2·39	2·49	...	2·42
1849	1·89	...	2·04	1·92	...	1·95
1850	2·13	...	2·08	2·19	...	2·13
1851	2·15	2·12	2·09	2·25	...	2·15
1852	2·41	2·50	2·44	2·58	...	2·48
1853	2·43	2·48	2·37	2·44	...	2·43
1854	2·31	2·22	2·31	2·37	...	2·30
Manured with Ammonia-Salts and Mineral Manure. (Mixed Plots.)						
1845	...	...	...	...	...	...
1846	2·20	2·14	...	2·14	...	2·16
1847	2·34	2·38	2·40	2·42	2·44	2·40
1848	2·36	...	2·40	2·42	2·48	2·41
1849	1·96	1·97	2·10	2·07	...	2·02
1850	2·16	2·28	2·25	2·25	...	2·23
1851	2·00	1·98	2·02	1·92	...	1·98
1852	2·43	2·34	2·31	2·40	2·32	2·36
1853	2·30	2·34	2·29	2·28	...	2·30
1854	2·16	...	2·12	2·07	...	2·12

ecessary to make a few remarks in reference to this Table
ıan one hundred nitrogen determinations. They were
ıe method of burning with soda-lime, and collecting and
s platinum salt in the ordinary way. Few, perhaps, who
made a limited number of such determinations, then
re and uniform substances, and who have not attempted
heir work at another period, with fresh re-agents, or by
f another operator, will imagine the range of variation
o be expected when all these adverse elements are to
influence. It is freely granted, that the variations
he Table between one determination and another, on one
ne substance, are sometimes more than could be desired.
ing, however, are the circumstances under which they
obtained. Experiments 1 and 2 were pretty uniformly
ıe same operator, but not all consecutively, or with the
ı of re-agents. It was thought, therefore, that inde-
of any variations between the two determinations, it
lesirable to have results so important in their bearings,
others. Accordingly, samples of each of the ground
e given under arbitrary numbers, to two other operators,
results are recorded respectively in columns 3 and 4;
a fifth determination is given, it is a repetition by one
the experimenters last referred to. We should observe,
ıve found it almost impossible to procure a soda-lime
ot give more or less indication of nitrogen when burnt
ganic substance not containing it; and hence we have
ıdopted the plan of mixing 1–2 per cent. of non-nitro-
ıstance intimately with the bulk of soda-lime, igniting
ıffle, moistening, and reheating it gently. After this
the soda-lime is free from ammonia-yielding matter.
further be remembered, that a ground wheat-grain is
ıns an uniform substance. Indeed, as we shall show
, some of the particles of which such a powder is com-
contain half as much again of nitrogen as others; and
nefficiency in the grinding, or error in taking the por-
alysis, may materially affect the result. Notwithstand-
se circumstances, and the admittedly undesirable range
ce in the several determinations in some cases, it will
d, that generally three at least of the numbers agree
closely, and in some cases the fourth also. In fact
a study of the detailed Table must give considerable
, at least in the direction of the variations between the
lts given in Table III, and in their sufficiency for the
founded upon them. With these remarks on the data,
eed with the discussion of Table III itself, which next

TABLE III.

	Particulars of Quantity.			Per-centages of Quality.									Composition of Grain.									Composition of Straw.								
	Total Produce (Grain and Straw) per Acre in lbs.			Per Cent. Grain to Total Produce.			Per Cent. Dressed Grain to Total Corn.			Weight Per Bushel of Dressed Grain in lbs.			Per Cent. Dry (212°.)			Per Cent. Ash in Dry.			Per Cent. Nitrogen in Dry.			Per Cent. Dry (212°.)			Per Cent. Ash in Dry.			Per Cent. Nitrogen in Dry.		
	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.	Unmanured.	Ammonia-Salts only.	Minerals & Ammonia-Salts.
1845	4153	6246		31·7	31·7	...	90·9	90·4	...	56·5	56·2	...	81·2	80·0	80·9	1·93	1·89	1·99	2·28	2·23	...	...	...	...	...	...	...	0·92	...
1846	2729	4034	4666	44·4	45·2	42·4	94·7	94·1	93·6	63·7	63·6	63·1	81·0	85·2	84·1	2·03	1·88	1·91	2·11	2·19	2·16	...	...	...	...	...	5·84	...	0·63	0·71
1847	3025	4593	5179	37·1	37·1	36·0	91·6	93·1	93·1	60·2	61·5	62·3	...	..	...	...	...		2·16	2·34	2·40	...	...	...	5·97	5·55	5·33	0·74	0·74	0·70
1848	2664	3701	4661	35·7	36·0	36·5	88·8	83·9	89·3	57·3	58·1	58·7	...	81·2	80·4	2·14	2·00	2·02	2·31	2·42	2·41	...	...	...	8·03	6·77	7·01	0·69	0·82	0·84
1849	2843	4992	5619	43·2	42·9	40·5	96·1	94·8	95·4	61·1	62·3	63·7	82·3	82·7	83·0	1·90	1·71	1·81	1·86	1·95	2·02	82·1	83·9	82·5	7·26	6·13	5·97	0·80	0·85	0·82
1850	2721	4810	5877	36·8	35·8	33·2	95·6	94·2	94·2	60·6	60·2	61·2	83·8	84·3	84·4	2·07	1·90	2·01	2·08	2·13	2·23	82·6	85·7	84·4	7·21	5·47	5·67	0·83	...	0·94
1851	2710	5036	5583	40·0	39·0	38·1	89·5	91·0	92·3	61·1	61·9	62·6	84·3	84·5	84·0	1·96	1·82	1·87	1·80	2·15	1·98	84·3	84·9	84·4	6·78	5·58	5·60	0·75	...	0·82
1852	2457	4107	4970	35·0	32·1	30·6	90·9	92·6	92·1	56·6	55·9	56·5	82·6	83·7	83·5	2·11	1·91	1·98	2·31	2·18	2·36	82·8	83·3	82·6	7·11	5·85	5·99	0·93	0·89	0·79
1853	1772	2691	4913	20·2	23·8	26·8	74·3	75·2	89·5	45·9	48·6	51·9	80·1	80·1	80·9	2·52	2·08	2·13	2·32	2·13	2·30	81·6	80·9	81·2	6·80	6·15	5·96	1·27	1·29	1·03
1854	3496	5808	8311	38·9	38·1	34·7	93·9	94·0	95·6	60·6	60·5	61·9	84·7	84·8	85·1	2·01	1·79	1·89	2·01	2·30	2·12	83·3	84·3	84·1	5·26	4·74	4·92	0·75	0·56	0·75
	2956	4688	5564	36·6	36·2	35·4	90·6	90·3	92·8	58·5	58·9	60·2	82·9	83·0	82·9	2·07	1·85	1·96	2·13	2·26	2·22	82·8	83·8	83·2	6·80	5·78	5·83	0·84	0·84	0·82

A glance at this Table III, shows that the *quantity* of produce ries very much indeed in one and the same season, according to e manuring. With these great differences in the *quantities*, pendent on manuring, we have far less marked differences in the *ality* of this ripened crop, dependent on the same causes; and is, with some few exceptions, is the same whether we look to the olumns indicating the general characters only, or the composition f the produce. That is to say, the same general distinctions etween the produce of one season and another, are observable nder the several varying conditions of manuring in each, as have een exhibited in the Table I of averages alone. In fact, season, climatic variations, are seen to have much more influence than anuring, upon the character and composition of the crop.

We have said that, other things being equal, the percentage nitrogen in our wheat-grain was the lower the more the seed s perfected; and we have also said, that nitrogenous manures atly aid the development of the crop. But, an inspection of columns of Table III which give the percentages of nitrogen the dry substance of the grains produced under the three ferent conditions of manuring specified, shows us that there is ost invariably, a higher percentage of nitrogen where ammo--salts alone have been employed, than where the crop was manured. We also see that, almost invariably, there is a higher rcentage of nitrogen where mineral manures as well as ammo--salts have been used, than in the produce of the corre-onding unmanured plots. A closer examination shows, however, ough the indication is not uniform, that there is nevertheless, obvious tendency to a lower percentage of nitrogen, where the neral constituents also have been employed, than where the mmonia-salts have been used alone; and with this, there is on e average, a somewhat higher weight per bushel, indicating gher degree of maturation. Then, again, what are the circum-ances of these experiments, under which an increased percentage nitrogen in the fixed substance of the produce, is obtained by supply of it in manure? The unmanured plot with its low per-entage of nitrogen in produce, is shown by the field experiments, be greatly exhausted of the annually available nitrogen, relatively the annually available mineral constituents required by the heat crop. The plot, with the ammonia-salts alone, is shown y the field results to be defective in the requisite and available inerals, relatively to the *available* nitrogen, and hence the crop

is grown under a relative excess of the latter. Again, the plots with mineral manures and ammonia-salts together, received so far an excess of the latter, as to yield, with the minerals, a larger crop than the average of the locality under rotation, and larger also, than the average of seasons would ripen healthily. It is then, under these artificial and abnormal circumstances, of the somewhat unnaturally low percentage of nitrogen, from obvious defect of it in relation to the developing and maturing capabilities of the season on the one hand, and the obviously relative excess of it on the other, that we got an increased percentage of nitrogen in wheat-grain by the use of it in manure. Even under these extreme conditions, the range of variation by manuring is very small; and there is nothing in the evidence that justifies the opinion, that, within the range of full crops and healthy maturation, the percentage of nitrogen in wheat-grain, can be increased at pleasure by the use of it in manure. That very opposite extremes of condition of soil-supply, may directly influence the composition even of wheat-grain, is however, illustrated in the percentages of mineral matter, as well as those of nitrogen, given in the table. Thus, taking the mean results only, we have with the relative excess of mineral constituents on the unmanured plot, the highest per cent in the produce; with the greatest relative defect on the plot wit ammonia-salts only, the lowest per cent. in the grain; and wit the medium relation in the other plots, the medium per cent. i the produce. Excepting, however, abnormal conditions, as alread remarked, variation in climatic circumstances, has much greate influence on the percentage-composition of wheat-grain, tha variation in manuring.

Let us now turn to the composition of the *ash* of wheat-grai Independently of the defect of a sufficient number of publishe analyses of wheat-grain ash, a dozen years ago, when we took u the subject, it was then generally believed that the compositio of the ash of vegetable produce, would vary considerably wit the supplies of the different constituents in the soil; it wa thought indeed, that according to the abundance of their presence one base might substitute another, as for instance *soda*, *potas* and so on. About the same time that we undertook a series wheat-ash analyses, the ashes of various succulent vegetables we also analysed. This latter investigation led us to conclude, that th fixity of the composition of the ash of such substances, depende *very much* upon the degree of maturation of the produce; and in

that some constituents—soda and chlorine for instance—
ırred in much larger quantities in the more succulent and
ipe, than in the more elaborated specimens. It seemed to be
fectly consistent with this experience, to find in the ash of a
ıparatively perfected vegetable product like wheat-grain, a con-
ɜrable uniformity of composition—such indeed as the analyses
ʏ to be recorded will indicate.

These analyses were made ten years ago, by Mr. Dugald
mpbell, and the late Mr. Ashford. And as, since that time,
methods of ash-analysis have in some points been improved
ɔn, it will be well to give an outline of the plan then adopted;
ɔcially as it is by a consideration of the tendencies to error on
ıe points, that we must interpret the bearings of the actual
ıres given. On this point we need only add, that Mr. Camp-
l fully concurs in the tenor of our remarks.

Method of Analysis:—Three portions of ash were taken.

No. 1. In this the sand, silica, and charcoal, phosphate of iron,
sphoric acid, lime, and magnesia, were determined. The ash
dissolved in dilute hydrochloric acid, evaporated to perfect
ɑess, moistened with hydrochloric acid, boiled with water, and
insoluble matter collected and weighed, as—*sand, silica, and*
coal. To the filtrate, acetate of ammonia was added, and
r digestion, the precipitate separated, dried, ignited and weighed
s *phosphate of iron.* To the filtrate now obtained, a solution
ı weighed portion of pure iron dissolved in nitro-hydrochloric
l was added, then acetate of ammonia, and the mixture
ɜsted until the whole of the iron was precipitated as phosphate
he peroxide with excess of peroxide, from which was calculated
phosphoric acid. From the solution filtered from the phos-
te of iron and oxide of iron, the *lime* was separated as oxalate
ignited as carbonate; and from this last filtrate, the *magnesia*,
phosphate of soda and ammonia.

No. 2. A second portion of ash was put into a carbonic acid
aratus, the acid, if any, evolved by means of nitric acid, and
ɔrmined by the loss. The solution being filtered, sulphuric
l was separated by nitrate of baryta; and afterwards *chlorine*
ɑitrate of silver.

No. 3. To a solution of a weighed portion of the ash in
rochloric acid, caustic baryta was added in excess, and the
cipitate separated by filtration; the excess of baryta was then

removed by carbonate of ammonia, and the filtered solution evaporated to dryness, the residue heated to redness and weighed; water added, any insoluble matter deducted, and the remainder taken as chlorides of potassium and sodium; a solution of chloride of platinum was now added to separate the *potash*; the *soda* being calculated from the loss.

It is now admitted, that the separation of phosphate of iron from the earthy phosphates by acetate of ammonia as above described, is unsatisfactory; and it is probable the amounts given in the tables as phosphate of iron are too high, and if so, part of the difference should obviously go to the earthy bases. For a similar reason it is possible that the phosphoric acid determinations may be somewhat too high—also at the expense of the earthy bases. Then again, it is well known that in practice the process for potash and soda, is one of some delicacy; and that the tendency of manipulative error is to give the soda somewhat too high. We conclude upon the whole, that our phosphoric acid determinations *may* be somewhat high; our phosphate of iron pretty certainly so; and probably the soda also; the other bases being, on this supposition, given somewhat too low.

The wheat-grain ash-analyses, 23 in number, and referring to the produce of three separate seasons, and of very various manuring, are given in the following Tables—numbered IV, V and VI respectively.

Analyses of Wheat-Grain Ash.

HARVEST, 1844.

Plot Numbers	2	3	5	1	9		15	16	18	Means.
Manuring, per acre	Farm-yard Manure; 14 tons.	Unmanured.	Superphosphate Lime, 700 lbs.	Superphosphate Lime, 700 lbs, Rape Cake, 150 lbs.	Superphosphate Lime, 616 lbs. Sulphate Ammonia, 65 lbs.		Superphosphate Lime, Potash and Magnesia, and Silicate Potash.	As 15, with Soda and Sulphate Ammonia, 65 lbs.	As 16, and Rape-Cake, 154 lbs.	
					Analysis 1.	Analysis 2.				
Characters of the produce:—										
Per Cent. Grain in Total Produce ...	46·4	45·2	46·1	46·4	48 3		46·9	46·8	43·6	46·2
Weight per bushel of Dressed Grain (lbs.)	59·2	58·5	58·2	59·0	62·2		62·0	62·5	62·0	60·4
Per Cent. Dry Substance in Grain (at 212°)	82·8	81·8	81·1	82·3	83·6		83·1	83·3	83·2	82·65
Per Cent. Ash in Dry Substance ...	2·06	2·17	2·25	1·88	2 00		2·02	2·03	1·96	2·05
Constituents of Ash:—										
Phosphoric Acid	48·13	50·84	51·02	50·48	49·92	49 98	50·39	51·43	49·28	50·16
Phosphate of Iron	2·56	2·45	2·62	2·10	2·32	2·55	3·00	2·54	2·75	2·54
Potash	28·91	30·22	29·37	27·40	29·06	29 45	29·09	28·33	28·53	28·93
Soda	·76	·00	·22	1·12	·90	·00	·00	·00	2·10	·57
Magnesia	11·84	11·04	11·81	10·10	10·84	10·36	10·86	11·38	11·38	11·07
Lime	3·77	3·00	3·18	2·71	3·39	3·73	3·17	3·31	3·48	3·30
Chlorine	Traces	·12	Traces	·52	·15	·11	·09	·21	Traces	·13
Silica, Sand, and Charcoal	2·64	2·72	1·49	5·45	2·57	2·21	1·86	1·47	1·70	2·45
Totals	98·61	100·39	99·71	99·88	99·15	98·39	98·46	98·67	99·22	99·15

TABLE V.

Analyses of Wheat-Grain Ash.

HARVEST, 1845.

Plot Numbers	2	3	5A	5B	6	15	17		Means.
Manuring, per acre	Farm-yard Manure, 14 tons.	Unmanured.	Superphosphate Lime in 1843-44. Unmanured.	Superphosphate Lime in 1843-44. Carbonate Ammonia (Solution).	Superphosphate Lime 112 lbs. Sulphate Ammonia 112 lbs. Rape Cake 560 lbs.	Bone-ash 224 lbs. Hydrochloric Acid 224 lbs. Sulphate Ammonia 224 lbs.	Superphosphate Lime 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs. Rape Cake 280 lbs. Analysis 1.	Analysis 2.	
Characters of the produce:—									
Per Cent. Grain in Total Produce	33·4	34·7	34·8	32·5	33·9	34·2	35·4		34·13
Weight per bushel of Dressed Grain (lbs.)	56·7	56·5	57·5	57·2	57·7	57·5	55·7		56·97
Per Cent. Dry Substance in Grain (at 212°)	80·0	81·2	81·1	80·9	81·7	80·9	80·6		80·91
Per Cent. Ash in Dry Substance	1·89	1.93	1·88	1·98	1·92	1·91	1·92		1·92
Constituents of Ash:—									
Phosphoric Acid	47·08	48·69	45·69	47·81	51·56	50·26	51·34	50·01	49·05
Phosphate of Iron	1·97	2·31	3·66	4·58	1·21	1·07	·80	1·20	2·10
Potash	25·16	28·53	29·06	28·87	31·75	32·27	30·20	30·47	29·54
Soda	8·01	·00	6·19	5·01	·00	·00	·68	·00	2·49
Magnesia	11·06	11·58	9·57	8·98	10·14	10·00	10·65	9·96	10·24
Lime	3·66	3·57	3·39	2·02	3·20	3·36	3·06	3·16	3·18
Chlorine	·00	·20	·00	·00	Trace	Trace	·40	·23	·10
Silica, Sand, and Charcoal	3·29	3·39	1·45	1·68	2·36	2·21	2·61	3·40	2·55
Totals	100·23	98·27	99·01	98·95	100 22	99·17	99·74	98·43	99·25

Analyses of Wheat Grain ——.

HARVEST, 1846.

Plot Numbers	2	3	1	8B	4	11B	Means.
Manuring, per acre	Farm-yard Manure, 14 tons.	Unmanured.	Bone-ash, 224 lbs.	Bone-ash, 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs.	Bone-ash, 224 lbs. Hydrochloric Acid 224 lbs. Sulphate Ammonia, 224 lbs.	Bone-ash, 224 lbs. Sulphuric Acid, 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs.	
Character of the produce:—							
Per Cent. Grain in Total Produce ...	42·7	44·4	43·6	43·6	42·6	43·1	43·3
Weight per bushel of Dressed Grain (lbs.).	63·0	63·7	62 6	63·6	63·5	63·2	63·3
Per Cent. Dry Substance in Grain (at 212°).	84·1	84·0	83·3	84·5	84·8	83·9	84·1
Per Cent. Ash in Dry Substance ...	2.07	2·03	2·04	1·91	1·99	1·91	1·99
Constituents of Ash:—							
Phosphoric Acid	50·01	49·89	50·62	49·47	48·73	50·08	49 80
Phosphate of Iron	1·65	1·66	3·10	2·52	2·62	3 06	2·43
Potash	30·03	30·60	27·93	29·58	31·00	29·18	29·72
Soda	·35	·25	·00	·00	·00	·00	·10
Magnesia	11·03	10·97	10·79	11·13	10·43	10·34	10 78
Lime	2·98*	2·89*	4·04	4·63	4·31	4·22	3·84
Chlorine	·12	·09	·30	·34	Traces	·17	·17
Silica, Sand, and Charcoal	1·88	2·17	2·18	2·54	2·62	3·00	2·40
Totals	98·05	98·52	98·96	100·21	99·71	100·05	99·24

* It would seem probable that in these two cases the Lime is given too low; but as the analyst, Mr. Ashford, is dead, no reference can be made, and we have unfortunately not had time to repeat the analyses prior to publication, as we had intended.



the phosphate of iron, and that portion of the matter insoluble, which may have been soluble silica—the wh on the average, amounting to a very few per cent.- wheat-grain is seen to consist essentially of *phospha* bases being potash, magnesia, and lime. The potash nearly one-third of the whole ash; the magnesia to than one-third of the potash; and the lime to about the magnesia.

If we now compare with one another the analyses different ashes in 1844, those of the seven in 1845, or 1846, having regard to the manures by which the grown, it is impossible to say that these have had an well-defined influence upon the composition of the ash Thus we find, looking at the Table for 1844, that se plots manured with superphosphate of lime, yield having no higher percentage of phosphoric acid than unmanured plot. Again, where potash is added (plots 18), the percentage of it in the ash is not greater than of the cases where it was not employed. And again, case where soda was employed (plot 16), there is none in the ash; nor, lastly, is the percentage of magnes increased by the use of it in manure. A similar det deration of the composition of the ashes of the seas

show the difference in composition, if any, dependent on *manure*, yet it is found to be quite adequate to indicate the marked differences in the *degree of development and maturation* of the grains, dependent upon *season*. Before calling attention to the figures illustrating this point, it should be remarked that the season of 1845 was the worst but one, and that of 1846 nearly the best, for ripening the grain, during the thirteen years of our continuous growth of wheat. And we shall find, consistently with this, and with the conclusions arrived at in connection with Tables I and III, that the variation in the composition of the ash is, comparing one year with another, much the greatest in the produce of the bad ripening season 1845, and much the least in the good ripening season 1846. This point, and some others, are illustrated in the following Summary Table, No. VII.

TABLE VII.

Composition of Wheat-Grain Ash.

	Variation in per Cent. in each Season.			Mean for each Season.			Means according to Manuring.			General Means.	
	1844 9 Cases.	1845 8 Cases.	1846 6 Cases.	1844 9 Cases.	1845 8 Cases.	1846 6 Cases.	Unmanured (3 years).	Farm-yard Manure (3 years).	Other Manures (3 years), 17 Cases.	23 Cases, Rothamsted.	26 Cases, Mr. Way.
Characters of the produce :—											
Per Cent. Grain in Total Produce ...	...	...	...	46·2	34·1	43·3	41·4	40·8	41·3	41·2	
Weight per bushel of Dressed Grain (lbs.)	...	...	...	60·4	57·0	63·3	59·6	59·6	60·1	60·0	
Per Cent. Dry Substance in Grain (at 212°)	...	...	...	82·6	80·9	84·1	82·3	82·3	82·5	82·4	
Per Cent. Ash in Dry Substance ...	...	...	...	2·05	1·92	1·98	2·04	2·01	1·97	1·99	1·69
Composition of Ash :—											
Phosphoric Acid	3·30	5·87	1·89	50·16	49·05	49·80	49·81	48·41	49·88	49·68	45·01
Phosphate of Iron	·90	3·87	1·45	2·54	2·10	2·43	2·14	2·06	2·45	2·36	0·82*
Potash	2·82	7·11	3·07	28·93	29·54	29·72	29·78	28·03	29·50	29·35	31·44
Soda	2·10	8·01	·35	·57	2·49	·10	·08	3·04	·95	1·12	2·71
Magnesia	1·74	2·60	·79	11·07	10·24	10·78	11·20	11·31	10·51	10·70	12·36
Lime	1·06	1·64	1·74	3·30	3·18	3·84	3·15	3·47	3·43	3·40	3·52
Sulphuric Acid	...	...	...	...	...	...	...	...	...	...	0·34
Carbonic Acid	...	...	...	...	...	...	...	...	...	...	0·02
Chlorine	...	...	...	·13	·10	·17	·14	·04	·14	·13	·13
Silica, Sand, and Charcoal	...	...	...	2·45	2·55	2·40	2·76	2·60	2·41	2·47	3·67†
Totals	...	...	...	99·15	99·25	99·24	99·06	98·96	99·27	99·21	100·03

* Peroxide of Iron. † Mr. Way gives this as soluble silica, exclusive of the sand and charcoal included with it in our own analyses.

Looking at the first Division of this Table VII, it is seen that he item of *phosphoric acid*, the variation in the percentage ng the several cases in each year, is the greatest in 1845, and least in 1846; in the *phosphate of iron*, it is the greatest in ; in the *potash*, it is the greatest in 1845, much less and t equal, in 1844 and 1846; in the *soda*, it is much the test in 1845, and much the least in 1846; in the *magnesia*, it ain far the greatest in 1845, and it is the least in 1846. In ase of the *lime*, we have an exception to this general indica- , dependent on the too low amounts of it given for Nos. 2 3, 1846; but if these are really in error in the direction ested at the foot of Table VI, the indication would be the e as for the other constituents. We have then in the circum- ces of the seasons, and in the comparative characters of the luce coincident with these variations, the evidence that for and the same description of grain, in a perfectly matured lition, the composition of the ash will be, within certain ow limits, constant.

So far as the constituents of the ash of the entire grain of wheat oncerned, we have only further to call attention to the three r Divisions of this Summary Table No. VII. In these are n, side by side :—

In the second Division of the Table, the mean composition of ashes for each of the three separate years;

In the third Division, the mean composition for the three years ther : (*a*) of the grain-ash from the unmanured plot—(*b*) of from the farm-yard manured plot—(*c*) of the grain-ashes all the other manures during the three years, including 17 s; and

In the fourth and last Division, the mean composition of all own wheat grain-ashes analyzed, 23 in number, by the side of mean of 26 analyses of the grain-ashes of wheat, of different riptions or grown in different localities, published by Mr. Way.

We will go into very little detail discussions of these mean lts, as the points they illustrate have most of them already n alluded to. We may first remark, as a point to which we ll recur further on, that the mean percentage of *lime*, is the t in the bad year 1845, and the greatest in the good year 1846. ain, it is greater in the average from the manured plots, than that from the unmanured. We may perhaps here anticipate saying, that this is at any rate consistent with what we shall

afterwards have to record, namely, that the ash of the finer flour —of which there is a greater proportion in the grain of the seasons of best maturation—contains more lime than that of the coarser and more branny portions of the grain.

Lastly, in reference to this Summary Table, we would call attention to the mean composition of wheat grain-ash yielded by the 26 analyses given by Mr. Way, by the side of that of the 23 specimens grown at Rothamsted. Mr. Way's analyses, equally with our own, show that wheat grain-ash essentially consists of phosphates of potash, magnesia, and lime. He, however, if we exclude silica, gives higher percentages of base, and a lower one of acid, than our own anaylses indicate. Mr. Way's average amount of phosphoric acid is indeed nearly 5 per cent. less in the ash than ours. His series, however, included many descriptions of wheat, and our own only one—the Old Red Lammas. In several of his cases, too, we observe that the percentage of this acid very closely approximates to our own average.

We have now given a summary view of some points of the composition of the entire wheat-grain, and of its ash, as affected by varying season, and various manuring. We next turn to an equally summary statement, of a large number of experiments made in reference to the *yield*, and *composition*, of the various products separated in the milling process. The grains operated upon with this view, were of the same description of wheat, but grown experimentally in different seasons, and under different conditions of manuring.

There have been many observations recorded as to the percentage of flour obtained in practice from 100 parts of grain, and in a subsequent Table some of these will be adduced. We are also indebted to M. Boussingault for the determination of the flour and of the bran, yielded by 24 different descriptions of wheat, all grown side by side in the Jardin des Plantes at Paris. His method was to powder the grains in a mortar, and separate the flour and bran by means of a silken sieve. Results of this kind can, perhaps, scarcely be compared with those of the ordinary mill. The differences exhibited between the different specimens were indeed very great; but the comparisons afforded within the series itself are interesting and very curious.

In our own experiments, the so-called *Colonist's steel hand-mill was first* had recourse to; as it was thought that by its use, rather

in that of an ordinary flour-mill, much smaller quantities of ain might be submitted to experiment, and that uniformity of rking would also be more within our control. It was soon ind, however, that in all cases the grain was, in this steel-mill, ther cut up than crushed and rubbed down, as between ordinary ll-stones. It was also found, that the action in this respect ried considerably according to the speed of the operator, and to e precise set of the mill, which required to be varied according the character of the grain. From these causes a statement of e *amount of the yield*, of the various products obtained from the eel hand-mill, would be of little value. Though further on we all have to call attention to some interesting points connected ith the comparative composition of the several products of the ains mechanically separated in this way.

We next determined to submit a series of the experimentally wn grains to careful, and as far as possible, uniform treatment ween the stones, and in the dressing apparatus, of an ordinary r-mill. The mill in question was worked by water-power. m 125 to 250 lbs. of the several grains were submitted to the eriment; the whole of the apparatus being carefully cleared of products of one specimen before another was commenced n. The weights and samples of the "*meals*" as furnished by stones, and of the several products separated in the dressing-hine, were taken under our own personal superintendence. en here, and although every possible precaution was taken, siderable irregularities in the action of the apparatus were ifest, depending partly on the varying characters of the grain. leed it was clear, that to obtain results as to comparative yield lour, strictly referable to the practical qualities of the respective ins, it would be necessary to operate on much larger quantities each than those even now taken, in order that the miller might re-adjust the set of his stones, as the work proceeded, according the character of the grain and of the meal which it afforded, as get from each its largest yield, as he would do in working upon siderable quantities. In all, twenty-eight lots of grain were rated upon in this way; and although, as above implied, and will be pointed out further on, the results might in some points ve been somewhat different with larger quantities, yet the ller, after a careful examination of all the products, decided at their general bearings were to be fully trusted.

In some cases the meal obtained from the stones was separated

in the dressing apparatus into nine products, and in others the products of the first three wires were taken together, constituting the bulk of the *fine* flour obtainable, and amounting to only about 70 per cent. of the grain. In practice, however, the fourth product of the dressing machine, "*Tails*," is generally redressed, and the fifth, "*Fine Sharps*" or "*Middlings*," reground and redressed, together raising the amount of good bread-flour to about 80 per cent., or sometimes more. The sixth product is called "*Coarse Sharps;*" the seventh, "*Fine Pollard;*" the eighth, "*Coarse Pollard;*" and the ninth, "*Long Bran.*" It should be stated, however, that mills vary very much in the arrangement of their dressing machines in different localities, and even in the same locality; so that the exact division of the products here given, will not apply invariably.

In Table VIII are given—

1st. In the upper division of the Table, the percentage yield in 100 meal, of each of the mill products, 7 or 9, as the case may be; each figure being the mean of several experiments.

2nd. (In the middle division of the Table)—The mean per cent. of dry substance (at 212°), in each flour, bran, &c. And,

3rd. The mean per cent. of mineral matter (ash), in each of the same mill products.

As will be seen, seven of the specimens were grown in 1846, nineteen in 1847, and two in 1848; and in order to give some idea of the general character of the produce yielding the results in each of the separate columns, there is given at the head the mean bushels per acre, the mean weight per bushel, and the mean per cent. of grain in total produce, of the specimens to which the column refers.

TABLE VIII.

the yield of the different Mill Products from 100 of Grain; and their Percentages of Dry Substance and Mineral Matter.

MEAN RESULTS.

	Products of Wires 1, 2, and 3.					Means of all in each year.				
	1846.		1847.		1848.					
	Taken separately.	Taken together.	Taken separately.	Taken together.	Taken separately.	1846, 7 cases.	1847, 19 cases.	1848, 2 cases.	Mean of all in the three years; 28 cases.	Distribution of Ash in the several Products of 100 Meal.
acters of Produce;—	Mean of 3 cases.	Mean of 4 cases.	Mean of 4 cases.	Mean of 15 cases.	Mean of 2 cases.					
els per acre	26½	29½	25½	33	31½	28	31½	31½	30½	
ht per bushel (lbs.)	63·5	63·3	61·7	62·2	59·1	63·4	62·1	59·1	62·2	
ain in total produce	43·5	42·7	35·9	36·0	37·1	43·0	36·0	37·1	37·8	
Yield of Flour, Bran, &c., in 100 Meal.										
... ...	44·0	...	35·7	...	47·4	44·0	35·7	47·4	41·1	
... ...	17·9	...	16·4	...	23·9	17·9	16·4	23·9	18·6	
... ...	8·7	...	13·3	...	2·0	8·7	13·3	2·0	9·2	
, 2, and 3, together.	70·6	68·3	65·4	71·5	73·3	69·3	70·2	73·3	70·2	
... ...	4·6	5·1	7·7	5·3	2·1	4·9	5·8	2·1	5·3	
s or Middlings ...	8·7	11·4	10·3	8·3	4·5	10·2	8·7	4·5	8·8	
rps	3·1	3·8	3·6	3·2	3·6	3·5	3·3	3·6	3·4	
d	1·8	5·5	1·9	1·8	2·6	3·9	1·8	2·6	2·4	
ard	6·6	2·7	7·4	7·1	7·9	4·4	7·2	7·9	6·5	
... ...	4·3	2·9	3·2	2·3	5·2	3·5	2·5	5·9	3·0	
'er Cent. Dry Substance (at 212° F.) in each Flour, Bran, &c.										
... ...	84·4	...	83·8	...	85·4	84·4	83·8	85·4	84·3	
... ...	84·5	...	83·7	...	85·2	84·5	83·7	85·2	84·3	
... ...	84·5	...	83·9	...	85·2	84·5	83·9	85·2	84·4	
, 2, and 3, together.	...	84·7	...	83·8	...	84·6	83·8	85·3	84·1	
... ...	84·4	85·2	84·3	85·2	85·5	84·8	85·0	85·5	85·0	
s or Middlings ...	83·1	84·9	84·0	84·7	85·3	84·1	84·5	85·3	84·5	
rps	86·5	85·1	82·2	86·2	85·4	85·7	85·3	85·4	85·4	
d	87·3	85·8	82·2	85·5	85·7	86·4	84·8	85·7	85·3	
ard	86·4	84·9	82·6	86·0	86·2	85·5	85·3	86·2	85·4	
... ...	86·3	85·5	83·1	85·6	85·7	85·8	85·1	85·7	85·3	
Per Cent. Mineral Matter (Ash) in each Flour, Bran, &c.										
... ...	0·70	...	0·68	...	0·70	0·70	0·68	0·70	0·69	·284
... ...	0·71	...	0·71	...	0·73	0·71	0·71	0·73	0·71	·132
... ...	0·75	...	0·74	...	0·87	0·75	0·74	0·87	0·73	·067
2, and 3, together.	...	0·71	...	0·70	...	0·71	0·70	0·77	0·71	·483
... ...	0·92	1·01	0·93	1·08	1·04	0·97	1·05	1·04	1·03	·054
s or Middlings ...	1·82	1·88	1·54	2·43	1·88	1·85	2·24	1·88	2·12	·186
ps	3·77	4·35	3·74	4·43	3·54	4·10	4·28	3·54	4·18	·142
d	5·86	6·01	5·45	5·65	5·03	5·94	5·61	5·03	5·65	·136
ard	6·91	6·85	6·41	6·39	5·84	6·88	6·39	5·84	6·47	·420
... ...	7·63	7·27	6·67	7·19	6·34	7·42	7·08	6·34	7·11	·213
Total	...	...	...	...	...	...	...	...	...	1·634

After the remarks already made, little need be said in detail regarding the comparative yield of the various products by 100 parts of the different meals. It was decided by the miller, that pretty uniformly there was too much flour left in the fourth, but particularly in the fifth product; and this, as an inspection of the Table will show, was obviated in the later experiments, namely, those on the grain of the harvest 1848. So far, then, the variation of the result is more due to the management of the miller, than to the intrinsic character of the grain.

It is more interesting to observe, that a very careful examination of all the products led to the conclusion, that the grains grown by the more nitrogenous manuring, and consequently in the larger crops, *provided they were well developed and matured*,* allowed a better separation of the flour, and less cutting up and intermixture of branny particles with it; and hence, yielded a cleaner bran than the grain of the poorer crops. This was not the case, however, unless the highly-manured crops were at the same time well developed. It is consistent with this character of the grain of the more highly-manured crops, that the produce of the heavier and richer wheat-lands is generally admitted to yield a larger proportion of flour. The fact that the grain of richly-manured crops is frequently coarse, and not the good miller's sample, arises from the circumstance, not of the direct effect of rich manuring in depreciating the quality of the grain, but because the larger crops are more subject to injury due to climatic circumstances, and are consequently frequently less favourably developed and matured.

It will be observed, that the amount of long bran is always more than 2, and in the year of badly-ripened grain (1848), it is nearly 6 per cent. of the total meal. This ninth product, together with the three or four immediately before it in the list, yield us nearly 20 per cent. of the total meal, of such a branny character as seldom to be used for human food. Some of the more recent experimenters, MM. Millon and Peligot for example, have concluded that the amount of actual woody fibre in wheat-grain is seldom more than from 2 to 3 per cent. On this supposition, the nearly 20 per cent. of the grain generally not applied directly as human food, would contain but a small proportion of necessarily indigestible woody matter; and it would appear that there was very great room for improvement in the modes of preparation of the grain, if

* It would appear that, in a good ripening season, this condition is best attained when the crop is cut before the grain is perfectly ripe.

ere desirable to separate as human food in the first instance, a er proportion of its nutritious matters. M. Poggiale, on the ır hand, maintains that the quantity of woody-fibre refractory he digestive organs, though not to chemical agents out of the y, is really very considerable.* But, of some points of the ıposition of the various products, we shall have to speak more detail presently.

In the second or middle division of Table VIII, we have the ɛrage percentage of dry matter in the different products. In ɛrence to these results it may be noticed, that, as might be ɔected, the percentage of dry matter is rather higher in the mill ducts, than it was in the entire grains which yielded them. s is particularly the case in regard to the two specimens of the vest 1848, the mill products of which give, on the average, a ıer per cent. of dry matter than the samples of either of the ɔr two years, although the dry matter of the entire grain of ; season (1848), was very low. The differences are therefore iously more due to the circumstances of preservation and after-tment, than to distinctions in the character of the respective ins. The only other remark which need be made regarding varying percentages of dry matter, is, that the branny, or more ɛrnal portions of the grain, have pretty uniformly a higher ɔentage of dry matter than the more farinal internal portions.

The widely differing percentages of *mineral matter* in the several l-products of the same grain, and the variations in this respect, n between the corresponding products in the different speci-ıs, in the same, or in different seasons, are both more striking, l of greater interest.

It is seen, that we have about ten times as high a percentage of in the ninth product, or bran, as in the first three, or purer rs. The percentage increases rapidly from the fourth to the th—that is to say, the greater the proportion of branny par-ɛs. A careful examination of the more detailed Tables also wed, that the variations in the percentage of mineral matter in corresponding products of different specimens of grain, had irect relation to the percentage, or relative position of the ɔective products, in the 100 of meal; in other words, to the

*Since the above was written, a very favourable report has appeared in the "Comptes lus" (January 12, 1857), by MM. Dumas, Pelouze, Payen, Peligot, and Chevreul e Commission appointed by the Academy of Sciences, to inquire into the matter ı a new process of M. Mège Mouriès, which claims to yield a perfectly white, lesome, and agreeable bread, employing 86—88 per cent. of the entire grain.

proportions of flour or of bran which they respectively contained. Although, however, the *percentage* of mineral matter is so very much greater in those portions of the grain which are not generally used in the first instance as human food, yet, an inspection of the last column of the Table, showing the *distribution* of the mineral matter in the several products of 100 of meal, according to the amount of each of these, will show that, even in our first three products, we have nearly one-third of the whole mineral matter of the grain; and adding to these a certain portion of that in the fourth and fifth products, which frequently contribute to the bread-flour, we shall have more than one-third of it in the currently edible portion of the grain. Further information as to the composition of the respective mill-products, and of their ashes, will be found in Tables IX, X, XI, and XII.

In Table IX are given the individual nitrogen determinations in each of the several mill-products; those in the first three columns being by one experimenter, and those in the fourth column by another. In Table X is given a collective view of the composition of the same products, in regard to some other constituents, as far as they have been determined; including also the mean results of Table IX.

TABLE IX.

Determinations of Nitrogen per Cent. in Mill Products of Wheat-Grain.

HARVEST 1846; GROUND 1848.

Description of Mill Products.	In natural state of dryness.				
	Experiments.				Mean
	1.	2.	3.	4.	
1. Wire 1	1·59	1·69	1·62	...	1·63
2. „ 2	1·64	1·73	1·69	...	1·69
3. „ 3	1·77	1·78	1·79	...	1·78
4. Tails	1·88	1 86	1·84	...	1·86
5. Fine Sharps, or Middlings ...	2·20	2·20	2·22	2·22	2·21
6. Coarse Sharps	2·58	2·52	2·59	2·62	2·58
7. Fine Pollard	2·43	3·37	2·48	2·48	2·44
8. Coarse Pollard	2·41	2·32	2·47	2 46	2·42
9. Long Bran...	2·37	2·37*	...	2·42	2·39

* By a third experimenter.

Composition of Mill-products of Wheat-Grain.

HARVEST 1846; GROUND 1848.

Description of Mill Products.	Flours, &c. from 100 Grain.	In 100 of each Product.			In 100 each Ash.		Distribution of Constituents in Mill Products of 100 Grain.			
		Dry Substance (at 212° F.)	Mineral Matter (Ash).	Nitrogen.	Insoluble in Acid.	Phosphoric Acid.	Mineral Matter.	Nitrogen.	In the Ash.	
									Insoluble in Acid.	Phosphoric Acid.
1. Wire 1	51·2	85·5	0·71	1·63	6·04	44·3	0·36	0·83	0·022	0·161
2. „ 2	24·8	85·6	0·74	1·69	5·83	45·5	0·18	0·42	0·010	0·083
3. „ 3	1·7	85·0	0·82	1·78	5·74	48·1	0·01	0·03	0·000	0·087
4. Tails	1·6	85·2	1·04	1·86	2·18	48·4	0·02	0·03	0·000	0·008
5. Fine Sharps, or Middlings ...	3·3	85·5	2·19	2·21	3·04	51·3	0·07	0·07	0·002	0·037
6. Coarse Sharps ...	3·3	86.1	3·93	2·58	3·84	49·6	0·13	0·08	0·005	0·064
7. Fine Pollard ...	1·8	86·5	5·46	2·44	0·84	52·3	0·10	0·04	0·001	0·051
8. Coarse Pollard ...	6·7	86·1	6·56	2·42	0·56	55·2	0 44	0·16	0·002	0·242
9. Long Bran ...	5·0	86·4	7·14	2·40	0·60	54·8	0·36	0·12	0·002	0·195
Totals ...	99·4	...	...	...	...	...	1·67	1·78	0·044	0·850

The grain to which Tables IX and X refer, was an equal mixture of the produce from four different plots, very variously manured, and grown in the season 1845–6; the harvest of which yielded one of the best-matured grains throughout our series of field experiments. The wheat in question was, however, not ground until 1848; and we have in the percentage-yield of the respective products, confirmation of the general opinion, that other things being equal, old wheat yields up its flour better than new. Thus, whilst in the average of the cases already recorded, we have little more than 70 per cent. of flour through the first three wires, we have from this old wheat 77¾ per cent. The products 4 and 5, from which a further yield of bread-flour is obtained, were correspondingly small; but Nos. 8 and 9 were, on the other hand, somewhat large.

The particulars given in Table X are the percentages of *Dry Matter*, of *Ash*, and of *Nitrogen*, in the respective mill-products of this mixed grain. There are also given the percentages of *Matter insoluble in Acid*, and of *phosphoric acid* in each of the nine ashes; and in the last four columns we have the *distribution* of the total mineral matter, of the nitrogen, and also of the insoluble matter, and phosphoric acid of the ash, in each of the nine products, according to the proportion of the latter in 100 of the grain or meal.

The percentage of *Dry Matter* in the several products from this old grain is, as would be expected, somewhat higher than the average from the grains of the same year which had not been so long stored. As before, the percentage of Dry Matter shows a tendency to increase as we proceed to the outer portions of the grain. The percentages of ash also show the same relations as already pointed out.

Referring to the column of the percentage of nitrogen in each of the nine separated products, we find that it is lowest in the products at the head of the dressing machine—that is, in the flours; and it is half as high again in the more branny portions. It is seen, however, to be the highest of all in the product No. 6; and somewhat lower in the coarser brans. It may be remarked, that the indications of the figures in this respect are at any rate consistent with such observations as have been recorded regarding the structural composition of wheat-grain; it being stated that the greatest concentration of nitrogenous compounds is immediately *below* the pericarp itself; and we should expect that the

›r bran would have less of the more internal matters adherent

he higher percentage of nitrogen in bran than in fine flour, requently led to the recommendation of the coarser breads as nutritious than the finer. We have already seen that the branny portions of the grain, also contain a much larger ›ntage of mineral matter. And further, it is in the bran that argest proportion of fatty matter—the non-nitrogenous sub-›e of highest respiratory capacity which the wheat contains—is l. It is, however, we think, very questionable whether, upon data alone, a valid opinion can be formed of the comparative ›s as food, of bread made from the finer or coarser flours from and the same grain. The published evidence at command leads he conclusion, that of the nitrogenous constituents of bran, a h larger proportion is soluble in water, than of those in the r flours. That is to say, there is in the bran, probably, a larger portion of the more universal vegetable compound, albumin, less of those more special to the grain of wheat; and hence we r perhaps conclude, that it exists in a less elaborated, and bably, therefore, less assimilable condition.* It is stated, on other hand, by Poggiale, that a large proportion of the insoluble ›genous constituents of bran, occurs in a form only in an ›rior degree digestible. Again, it is an indisputable fact, that nny particles, when admitted into the flour in the degree of ›erfect division in which our ordinary milling processes leave m, very considerably increase the peristaltic action; and hence alimentary canal is cleared much more rapidly of its contents. is also well known, that the poorer classes almost invariably fer the whiter bread; and among some of them who work the lest, and who consequently would soonest appreciate a diffe-›e in nutritive quality (navvies for example), it is distinctly ed, that their preference for the whiter bread is founded on fact, that the browner passes through them too rapidly; con-tently, before their systems have extracted from it as much ›itious matter as it ought to yield them.

* According to M. Mège Mouriès, before referred to, a portion of the soluble genous matter of bran exists as a peculiar body, *Cerealine*, which when dis-d up from bran in water at a given temperature, effects the solution of the rent starch also. His process of extracting from the bran an additional unt of the bread-material which the grain contains, consists in fermenting, the addition of some glucose, an infusion of the finer brans, straining off the ly matter, and using the fluid in making up the dough with the finer flour.

It is freely granted, that much useful nutritious matter is, in the first instance, lost as human food, in the abandonment of 15 to 20 per cent. of our wheat-grain to the lower animals. It should be remembered, however, that the amount of food so applied, is by no means entirely wasted. And further, we think it more than doubtful, even admitting that an increased proportion of mineral and nitrogenous constituents would be an advantage, whether, unless the branny particles could be either excluded, or so reduced as to prevent the clearing action above alluded to, more nutriment would not be lost to the system by this action, than would be gained by the introduction into the body coincidentally with it, of a larger actual amount of supposed nutritious matters. In fact, all experience tends to show, that the *state*, as well as the chemical composition of our food, must be considered; in other words, that its digestibility, and aptitude for assimilation, are not less important qualities, than its ultimate composition. Observation also tends to show, that elaboration, or maturation, have their influence in determining the digestibility or the assimilability of our food—both the vegetable and animal. But to this point we shall refer again presently.

Returning to the experimental results in Table X, the next point of remark is as to the amount of matter *insoluble in acid*, in the ash of the respective mill-products. It is seen, that the percentage of such matter is very much greater—indeed in this particular case, ten times greater—in the ash of the finest flour, than in that of the coarsest bran. It was at first thought that this must be an error. Some repetitions were therefore made, and the products of the steel-hand-mill were also examined; when it was found that the result in question was fully confirmed. It would be interesting to examine the series, to determine what proportion of this insoluble matter is really proper mineral constituent of the respective products, and how much adventitious merely. On consideration, it will however be clear, that the process of dressing the meal would tend to shake and clean the bran, from all adherent matters; which, if silicious, as well as the particles arising from the abrasion of the mill stones, would naturally be found among the heavier products at the head of the machine. That is to say, they would be found in larger proportion in the flour, whilst the bran, by the mechanical methods of its separation, would be almost entirely freed from them. According to published analyses, it would appear, however, that *silica*, as

iguished from merely insoluble sandy matter, does exist to a derable, though variable extent, in the ash of entire wheat- ı. And from the results now given, it may perhaps be luded, that this constituent found to exist so constantly in ə animal substances, does really occur in larger amount in e portions of wheat-grain which are best adapted as food?

Phosphoric acid, on the other hand, is seen to be in smallest portion in the ash of the flour at the head of the dressing hine; and the percentage pretty gradually augments as we ceed from the finer to the coarser and more branny portions, ash of the latter being far the richest in this essential acid.*

It may further be remarked in reference to the varying compon of the ash of the different mill-products, that in several s we have found the *magnesia* greatly to increase as we pro- from that of the finer to that of the coarser products. The entage of *lime* is, on the other hand, greatest in the ash of the s, and less in that of the brans. This latter point is consistent a tendency discernible, to an increase in the percentage of in the ash of those grains most matured in one and the same on, or in the ash of the grains grown in a season of higher uring character. We may further conclude, from the great ease in the percentages both of the phosphoric acid, and of magnesia, as we proceed from the ash of the flours to that of brans, and also from the very slight compensation from the rease in that of the lime (the total amount of lime being tively small), that the chief complementary constituent of eat-grain ash—namely, *potash*—will occur in larger proportion the ash of the flours than in that of the brans; hence, its larger ount will be coincident with the larger amount of silica.

In the last Division of Table X is shown the *distribution* in the pective products from 100 of grain, or its meal—of the nitrogen, the total mineral matter, and of the insoluble substance and sphoric acid of the latter—which the entire grain contained.

It will be seen, that notwithstanding the percentage of nitrogen so much greater in the branny products, yet owing to the smaller ount of these, by far the larger proportion of the total nitrogen the grain is accumulated in the flours. In fact, in the case

* Probably a portion of the phosphoric acid existing in wheat-grain-ash is due the oxidation, during incineration, of phosphorus, found by Professor Voelcker exist in such large amount, associated with the nitrogenous bodies. See also ofessor H. Rose on this subject—Poggendorff's Annalen, vol. lxxvi. p. 305.

before us about three-fourths of the nitrogen would be accumulated in those of the products which would be ordinarily used for bread, or for human food in other forms. On the other hand, only about two-fifths of the total mineral matter would be found with this three-fourths of the nitrogen. Of the *phosphoric acid* again, the larger amount is distributed in the branny portions; only about one-third of it being obtained in the bread flours. At the foot of these columns of the distribution of the constituents, the percentage in the entire grain or meal of the items as determined by analysis in each separate product, is given by the addition of these items so obtained; and the percentage so calculated agrees very closely with that which the analysis of the entire wheat-grain or its ash would indicate. Thus we may mention, that according to the sum of the phosphoric acid distributed in the different products, we have 50·7 per cent. of it in the ash of 100 of grain or meal; whilst the average percentage obtained in the analyses of the six ashes of the produce of the same season, was 49·8, an approximation sufficiently near to give some confidence, at least in the relative accuracy of the numerous analytical results involved in such an estimate.

Before leaving the question of the comparative chemical composition of the different products obtained by means of mechanical separation from wheat-grain, attention may be called to some results of this kind, in connection with the products of the Colonial steel-hand-mill, which was first employed in these experiments. As will be seen, the results now to be recorded agree in general tendency with those already given; yet they have some special and curious points of interest. The individual nitrogen determinations are given in Table XI, and the collected results of the examination of the various products in Table XII.

TABLE XI.

Nitrogen per Cent. in the Products of Wheat-Grain, from the Colonial Steel-hand-mill.

(In natural State of Dryness.)

Products from	Wheat-Grain, Harvest 1846.					
	Unmanured.			Manured.		
	Experiments.		Mean.	Experiments.		Mean.
	1.	2.		1.	2.	
irst Grinding:—						
Wire 1	1·94	1·89	1·91	1 59	1·60	1·59
Wire 2	1·57	1·59	1·58	1·44	1·49	1·47
econd Grinding:—						
Wire 1	1·89	1·90	1·89	1·60	1·61	1·60
Wire 2	1·73	1·78	1·76	1·53	1·65	1·59
Wire 3	1·78	1·76	1·77	1·58	1·49	1·54
Bran	2·07	2·09	2·08	1·69	1·79	1·74

TABLE XII.

Composition of the Products of Wheat-Grain from the Colonial Steel-hand-mill.

Products from	Wheat-Grain, Harvest 1846.								
	Unmanured.					Manured.			Mean of 5.
	In 100 of each Product.			In 100 of each Ash.		In 100 of each Product.			Ash in 100 of each Product.
	Dry Substance (at 212°F.).	Mineral Matter (Ash).	Nitrogen.	Phosphoric Acid.	Magnesia.	Dry Substance (at 212°F.).	Mineral Matter (Ash).	Nitrogen.	
First Grinding:—									
Wire 1	84·0	0·78	1·91	45·3	6·95	84·4	0·78	1·59	0·75
Wire 2	85·2	0·77	1·58	45·0	6·25	83·9	0·79	1·47	0·78
Second Grinding:—									
Wire 1	85·0	1·23	1·89	49·7	9·04	84·8	1·02	1·60	1·22
Wire 2	85·0	1·17	1·76	52·0	9·09	85·3	1·07	1·59	1·24
Wire 3	85·4	1·83	1·77	51·4	11·20	85·4	1·70	1·54	2·01
Bran	86·5	5·76	2·08	53·0	13·57	87·3	5·64	1·75	5·70

t should be mentioned in reference to the working of the steel--mill, that on passing the grain through the apparatus, four ıcts were first obtained, namely, two fine flours, thirds, and ; the last two products of the first grinding being mixed her, were passed through the mill a second time, and four ıcts again separated. After this explanation, the designation he products in Tables XI and XII will be sufficiently ligible.

Vith the information derived from the previously recorded ts, a glance at the percentages of ash in the several products e different grains, as given in Table XII, will show that the lled "bran" here obtained, retained more flour than from the ıary flour-mill. In fact it was obviously pretty nearly equi- ıt to the 9th, 8th, 7th, 6th, and part of the 5th products of ordinary mill taken together. The five flours, on the other , but especially the three from the second grinding, obviously ıined rather more branny particles than the ordinary bread- ı of the other series of the experiments. Such, indeed, the obvious character from an inspection of the various ıcts.

onsistently with the character of the products thus defined, ariations in their percentages of nitrogen are, upon the whole, ı less than in the former series; but such as they are they are curious. Thus in both instances, though in a less marked ıe in the manured than in the unmanured specimens, the first ıct of the first grinding, gives a higher percentage of nitrogen the second; that of the latter being in both cases exceedingly In the products of the second grinding, the tendencies are parallel in the two series. Here again the first product a higher percentage of nitrogen than the second. The third ıut equal to the second; and the fourth, or bran, is in both the highest of the six products in this respect. Following ese curious results, which show that the mechanical means yed had the tendency, even within the limits of the farinal of the grain, to separate products of different chemical cters—we may observe, that the fluctuation in the percentages h, are in detail strongly confirmatory of the direction of the tions in the amounts of nitrogen. Thus, whether we look to verage percentages of nitrogen and of mineral matter respec- r, as influenced by season, and as illustrated in the Summary ı No. I—or to the parallel amounts in the several mill-pro-

ducts as shown in Table X, we see that with a rise in the percentage of nitrogen there is, in comparable cases, one in that of the mineral matter, and *vice versâ*. If with this point in view, and carefully considering the degree of these changes as shown in our more detailed Tables, we compare together the columns of nitrogen and of ash, we find that the fluctuations in the latter as seen in Table XII, are perfectly consistent in direction with those in the former. This is more particularly observable in the products of the unmanured specimen.

The middle Division of Table XII, shows as before, a rise in the percentage of the *phosphoric acid* in the ash, as we proceed from the finer to the coarser products. The *magnesia*, too, follows the same order, the ash of the "*bran*" containing about twice as much as that of the flours of the first grinding.

In the last column of the Table XII, for the sake of comparison with the individual results in the former ones, we have the mean percentage of mineral matter for each product, of five lots of grain which were similarly experimented upon in the steel-hand-mill.

The next step in the prosecution of our inquiry would obviously have been—to separate the different proximate organic compounds of some series of these grains and their various mill-products—to determine the amount and composition of the mineral matters associated with each—and to submit the different grains, and their mechanically separated parts, to microscopic examination. Had this been accomplished, the results would probably have been of high interest to the vegetable physiologist; and they would probably have tended to throw some light on the functional actions or special offices, of the different mineral constituents known to be essential to the growth and elaboration of vegetable products. This labour, however, from pressure of other investigations, we have hitherto been obliged to forego; though several series of the mill-products themselves (necessarily to a certain degree artificially dried), and also of their respective ashes, have been preserved with a view to the prosecution of the subject, either by ourselves or others, at some future time, as far as such specimens will allow.

A great many scientific observers have investigated the questions—of the practical yield of bread-flour from 100 of grain [illegible] *meal—of the* produce of bread from 100 of flour—of the amoun[illegible]

lry substance, of water, and of nitrogenous compounds, in d—and of the changes which the flour undergoes in the bread-ing process. The question as to what are the chemical ities upon which depend the practical estimate of the miller the baker, of the comparative values of different flours for the oses of bread-making, has also frequently been discussed; conclusion generally arrived at being, that it is the percentage unt of nitrogen or of gluten which rules this practical estimate. opinion that the comparative value to the *consumer*, too, is surable by the same standard as to chemical composition, is pretty universal. With regard to the latter points we may at observe, that the tendency of more recent investigations is, east to modify, the currently adopted views. That this was rable, the whole course of our experimental inquiry and obser-on, during the last twelve years, has led us to believe; and we e occasionally treated of the subject in some of its aspects where.

Without hoping to settle dogmatically, questions involving too ıy factors to be dealt with in such a manner, we propose now dduce some few experiments and arguments of our own, which have a bearing upon some of those above enumerated; and hall also provide as summary a view as possible, in a tabular ı, of such published results of others, on some of the points ble of illustration in that way.

In the following Table XIII, are given:—

1st. The results of some experiments of our own, on the amount of bread yielded by 100 of the flour taken from the different parts of the dressing-machine; in some cases using the products of each of the first 4 wires separately, and in others (19 in number), taking the products 1, 2, and 3, mixed together.

2ndly. The determinations (at 212° F.) of the dry substance, and of water, in Country, and in London bakers' loaves.

3rdly. The recorded results of others, on—the yield of flour from 100 of grain—the yield of bread from 100 of flour—and on the percentages of dry substance, and of water, in bread.

TABLE XIII.

Bread made Experimentally.

	Number of Experiments.	Particulars of the Grains.				Flour from 100 grain.	Bread from 100 Flour.	In 100 Bread.	
		Harvest.	Bushels per Acre.	Pounds weight per bushel.	Per cent. Grain in Total Produce.			Dry Substance.	Water.
Product of Wire 1	6	1846 and 1847	25½	62·3	38·1	37·1	132·9	64·1	35·9
Do. do. 2	6					15·7	135·3	62·5	37·5
Do. do. 3	6					12·9	136·7	61·9	38·1
Do. do. 4	4	1847	25½	61·7	35·9	7·7	136·1	63·6	37·4
Total, or Means	...	...	...	...	...	73·4	135·2	62·8	37·2
Products 1, 2, and 3, mixed	19	1846 and 1847	32	62·4	37·2	70·8	137·8	61·4	38·6

Baker's Bread.

Mean of 4 Country Loaves 8 hours out of Oven	62·1	37·9
Mean of 3 London Loaves 12 hours out of Oven	64·2	35·8
Means	63·0	37·0

Recorded Observations.

	Flour from 100 Grain.	Bread from 100 Flour.	In 100 Bread.	
			Dry Substance.	Water.
PEREIRA	...	128·0		
,, ...	...	134·0		
DAUBENY	82·0			
DUMAS	...	128·0		
,, ...	...	130·0	62·5	37·5
,, ...	...	133·0		
URE—				
Practical Average	...	133·3		
Paris (in 1835) Best Flour	80·0	127·0		
HASSALL	77·7			
ALISON AND CHRISTISON (for Scotch Poor Law Board)	...	...	62·0	38·0

Recorded Observations—*continued.*

	Flour from 100 Grain.	Bread from 100 Flour.	In 100 Bread.	
			Dry Substance.	Water.
—				
... ...	75·7	150·0	56·0	44·0
and French Ration	...	...	49·0	51·0
ULT—				
... ...	72·0			
... ...	74·0			
... ...	...	130·0	64·6	35·4
bronn	...	140·0	57·1	42·9
Ration	...	139·0		
ion...	78·0			
... ...	83·0			
ale...	85·5			
... ...	80·0			
Ordinary	...	...	64·0	36·0
„	...	...	62·0	38·0
Ration	85·0	...	61·0	39·0
„	80·0	...	58·0	42·0
Cubic Loaf	...	...	60·0	40·0
„	...	...	52·0	48·0
	Calcd.	Expt.		
... ...	136·0	135·0	65·0	34·98
... ...	137·0	137·0	63·4	36·6
... ...	131·5	132·0	63·5	36·5
... ...	136·0	134·5	61·3	38·7
... ...	133·0	133·0	63·3	36·7
... ...	134·5	133·0	65·5	34·5
... ...	135·0	134·0	66.0	34·0
... ...	137·0	137·0	64·9	35·1
... ...	133·0	134·0	60·5	39·5
Mean	134·8	134·4	63·7	36·3
y	...	...	58·0	42·0
... ...	...	...	57·0	43·0
	Nit. Mat.			
—				
s First Quality ...	7·55	...	134·7	64·25	35·75
Second „ ...	7·99	...	...	65·09	34·91
baked, First Quality ...	7·29	...	131·0	66 1	33·9
Second „ ...	8·71	...	133·0	58·3	41·7
nented, First „ ...	7·00	...	143·0	60·5	39·5
Second „ ...	7·40	...	...	58·5	41·5

Setting aside the incidental but much accounted measure of the quality of flour—colour, it may be said, that the standard of excellence of the baker, is founded on the weight of the loaf, which, consistently with proper texture and lightness, can be obtained from a given weight of flour. Leaving for the present the discussion of the question upon what point or points of chemical composition, these properties individually or collectively depend, we may observe, that so far as our own experiments on the small scale go, the quality of yielding the greatest *weight* of bread from a given amount of flour, certainly did not seem to attach to the highest separated product of the dressing-machine; which, according to the results recorded in Table X, would probably contain slightly the smallest proportion of nitrogen, and consequently the largest amount of the starch series of compounds. On the other hand, looking at the results more in detail than they are given in the Table, it appears that the products of the grain of 1846 gave a notably greater weight of bread than the corresponding product of the more highly nitrogenous grain of 1847—the grain of the former year being admittedly a somewhat fuller and better sample than that of the latter. Judging then between the different products of the same grain, the experiments showed the weight of bread from a given weight of flour to be greater as we proceed from the less to the more nitrogenous products, so long as the comparison is made between the first three or fine flours only. The fourth product, however, containing still more nitrogen, but probably in a different condition, gave a less proportional weight of bread, notwithstanding that it also contained a considerable amount of branny particles, which it has been stated, have the property of retaining water by virtue of their structure independently of mere chemical composition. Comparing year with year on the other hand, the separate products of the grain of higher weight per bushel, of lower nitrogen, and admittedly of the best development, afforded the largest produce of bread.

Passing from the experiments on the individual products to those on the mixture of the first three of them, which would together constitute a *fine* bread-flour, we see that with this combination there was, on the average, a higher yield of bread than from either of the separate products. This was not the case taking the flours of 1846 alone; but it was remarkably so with those of 1847, the season of rather higher percentage of nitrogen; and it *should* be added, that whilst on the average the mixed products of

846 represented only 68·3 per cent. of the entire grain, those of 847 represented 71·5 per cent. Although, however, there is hus observed a tendency to increase in the *weight* of bread, the igher the percentage of nitrogen within the range of the finer lours, and especially so when mixed, yet the grains and the flours of 1846, were pronounced by an experienced miller, to be superior to those of 1847, and they would doubtless have given, on the large scale, a loaf whiter, lighter, and of better texture.

In all these trials exactly the same treatment was adopted, but as the result may be different in operating upon small and large bulks respectively, the method followed should be described. 32 ounces of flour were taken, and given weighed quantities of compressed yeast, and of salt, were always employed. Water of a uniform temperature was also used, and was worked in by a practised hand, until the dough was decided to be of the proper consistency. The weight of water taken up, was then determined. The dough was always made quite late in the evening, and after being allowed to ferment during the night, it was put into a baker's oven early the following morning. Finally, the loaves were weighed hot from the oven, and again when quite cold, towards evening. From the second weight, the increase upon the original weight of flour was ascertained; and, the percentage of dry substance in the flours being previously known, the percentages of dry matter and water in the bread were calculated, making no allowance, however, for the probably ½ per cent. of dry substance lost by fermentation. The experiments of Millon given in the lower part of the Table XIII, as well as the conclusion of other recent experimenters, indeed seem fully to justify the assumption, that the loss from that cause perhaps need not be estimated at more than the small amount above supposed.

For the sake of comparison, and as a check to our own bread-making experiments, and calculations thereupon, three loaves were bought at random, at as many different bakers in the city of London, and four from as many in our own locality in the country; and upon half of each of these, first finely divided, the dry substance was determined in a water-bath at 212° F. It will be seen, that the mean of our own experiments with the separate products, gives, by calculation as above alluded to, 62·8 per cent. dry substance, and 37·1 water, in the bread; and that with the products 1, 2, and 3 mixed, gave 61·4 dry matter, and 38·6 water.

The four country bakers' loaves (in July 1856—probably from wheat of 1855), gave 62·1 dry, and 37·9 water; and the three London ones 64·2 dry, and 35·8 water. It is thus seen, that our own results from the various flours of grain from two different harvests, agree very closely with those of the country bakers' bread from a third. They, together, indicate an average of 37 to 38 per cent. of water in the bread. The London bakers' loaves, which, however, had probably been four hours longer out of the oven than the country ones, gave 64·2 of dry = 35·8 of water. Upon the whole, then, these experiments, from the flours of three different seasons, indicate a probable average range of from 36 to 38 per cent. of water in bread; and, taking an average of 15 per cent. water in flour, and assuming the loss of dry matter by fermentation, and the gain by fixed saline matter added, to about neutralize each other, this would be equivalent to, from 132·8 to 137·1 parts bread for 100 of flour.

A reference to the recorded results of others, as given in the Table (XIII), will show that this average of 36 to 38 per cent. of water in bread, agrees very closely with the estimate of Dumas: with that of Payen, for the ordinary bread of Paris; with that of Boussingault, for Paris bread; with the mean of four kinds of fermented bread experimented upon by Dr. Maclagan; with that of nine by Millon; and with the estimate of Alison and Christison. The estimate by Payen, of 40 to 48 per cent. of water in the English cubic loaf, is undoubtedly too high for English bakers' bread as usually sold. The estimates by Johnston, of 44 per cent. water in English bread, and of 51 per cent. in English and French ration-bread, are also, no doubt, too high. The results of Boussingault in France agree with our own in England, in showing country bread to contain, usually, more water than that of the cities. Ration-bread seems, according to most observers, to be moister than that in ordinary use. To conclude on this point, although it is very desirable to have a proper estimate of the probable average proportion of dry substance contained in the most important article of the food of our population, yet it is obvious that many circumstances must influence the amount in individual cases. The length of time that the bread has been withdrawn from the oven, must of course be taken into account; but in fixing general averages, perhaps it is better to take it within the first twelve hours, as this will best represent the weights as

ivered by the baker, and, consequently, those estimated as ısumed.* It must be remembered, too, that the character of › ripening season greatly affects the quality of the flour, and giving from the results of others as well as of ourselves, a ›bable average of 36 to 38 per cent. water, or 62 to 64 per cent. dry substance in bread, we would at the same time remark, that our own special data, are derived from experiments on the pro-ıce of three seasons of higher than average maturing character.

That the *season*, independently of either soil or manuring, may ery much influence the percentage of nitrogen in one and the ıme description of grain, even in the same locality, is amply ustrated by the results in Tables I and III, given at the com-encement of this paper. It cannot be wondered at, therefore, at different localities or countries, should yield us grains showing wide range of variation in their percentages of nitrogenous mpounds. MM. Rossigneau, Boussingault, Millon, and eligot have examined many of the characteristic wheats of mmerce, and we propose here to subjoin some additional facts ating to this branch of the subject.

In the following Table (XIV) are given the mean results of a eat many determinations, by the mechanical method, of the *gluten* flour, by Mr. W. Constable, of Brighton. It is admitted that is method is an uncertain one, and it is, of course, quite incom-etent to indicate the *total nitrogenous* substance of the flours. owever, we believe the experiments to have been made with reat care and uniformity of manipulation, and, as they are also nsistent with results of another kind, they are well deserving cord. It may be premised that, whilst the method in question liable to a little depreciation in the amount of gluten by loss in ıe washing—especially when the substance itself is of an inferior ıaracter—yet, on the other hand, the drying is more likely to be error in the other direction. These two sources of error, there-re, so far as they operated in the experiments, would tend to utralize each other. It may be added, that not the least inte-sting part of Mr. Constable's results, is that he, consistently ith the observations of Peligot and others, establishes a very wide ange in the *character* of the gluten obtained from different flours,

* It should be stated, however, that, if the fresh weight of the 7 baker's loaves amined were assumed to be 4 lbs. each, as it should have been, then the dry matter hich the loaves contained was, on the average, only equal to 60¼ per cent.; the ater, on the same calculation, being, of course, 39¾ per cent.

as to colour, tenacity, elasticity, and so on. Mr. Constabl results, with which he has kindly furnished us, are recorded him seriatim, in the order in which they were obtained, and with any special reference to the point for the illustration of which here adduce them. It will be seen that, in our Table, we ha classified the results according to their reputed locality of grow or shipment, and arranged the *means* so obtained somewhat in t order of latitude, ranging from north to south, adopting the sa general arrangement for the European and American samp respectively.

TABLE XIV.

Percentage of Gluten in different Flours.

Mean Results.

Reputed Localities of Growth or Shipment.	Number of Experiments.	Mean Gluten Per Cent.
America —		
Canada	6	9·8
Genessee (New York)...	7	9·8
Other New York	7	10·1
Ohio	18	11·8
Maryland	3	11·3
Richmond (Virginia)	8	11·8
George Town (South Carolina)... ...	18	13·7
New Orleans	1	13·4
Miscellaneous	11	9·35
Mean...	79	11·4
North Europe -		
Dantzig	4	8·9
Hamburg	8	10·3
Stettin		
Pomerania		
South and East Europe—		
Tuscany	8	10·3
Spain		
Portugal		
Black Sea, Soft	2	12·5
Black Sea, Hard	9	14·9
Mean...	31	11·6
England —		
White	45	10·8
Red	13	10·4
Not Specified	45	10·5
Mean...	103	10·7

cannot fail to be observed, that there is a general tendency in ecimens from both the European and American continents, ease in the percentage of gluten, proceeding from the north south. It may therefore be concluded that, among other istances, a relatively high temperature at the ripening period urable to a high percentage of gluten. The mutual adap- s of heat and moisture, throughout the various stages of the ss of the plant, are, however, so almost infinitely varying, rom season to season, in one and the same locality, that it is rprising there should be many exceptions to any such sweep- neralization as the one here indicated, in regard to widely ng localities. A study of the variations in the character of op, and in the composition of the grain grown from year to n our experimental field, side by side with the varying cir- ances of root and leaf supply of moisture, and of tempera- is sufficient to show how numerous, and how indeed hanging in their mutual relations, are the factors which o one or another order of development in the growing

e have at various times determined the nitrogen in individual ens of foreign wheat which have come in our way, and recently, gh the kindness of Mr. W. J. Harris, of Fenchurch Street, n, we have been provided with a series of characteristic samples, sult of the examination of which we had hoped to embody in per. Unfortunately, the laboratory work is not sufficiently eted to allow of this, any further than by a few general ks on the tendency of the results already obtained. This cy, from the examination of a series of contrasted samples, y to confirm the indications of Mr. Constable's results as to l influence of latitude, or locality, on the nitrogenous per- e of the grains. There are, however, as above inferred, some sting and instructive exceptions brought to light. It is s, too, that both soil and variety, must have much to do with aracter of the grain; and that to elicit without exception, fluence due to climate alone, the same description of wheat l be grown in as far as possible similar soils, in different ies, for a series of years consecutively. In defect of specimens s kind, we must to a certain extent rely on the assumption, hose descriptions will be generally cultivated in a particular ty, which experience has shown to be most adapted to its te and other characters, and that hence the qualities of the

grains, will be at least some indication of the general tendencies of the climatic circumstances which have yielded them.

It may be remarked, that among the American specimens examined by Mr. Constable, the Genessee is seen to contain the lowest average percentage of gluten, yet it is one of the most highly esteemed of the American flours imported into this country. Again, among the foreign European samples enumerated, the Dantzic yielded the smallest percentage of gluten, whilst it has above all the highest range of value in the English market. The soft Spanish is perhaps the next in order of value among the imported European wheats, and we may observe that it is also one of the lowest in percentage of nitrogen which we have yet examined. On the other hand, the flours from many of the *highly* nitrogenous foreign wheats, have the undoubted character of imparting great "*strength*" to the dough, and for this purpose they are much valued to *mix* with weaker flour; especially with that from grain which has been imperfectly developed and matured. Some of the most important of these highly nitrogenous wheats are, however, both inferior in the colour of their flour, and very hard and horny; and owing to the inappropriateness of the English method of milling, to the defective whiteness of the flour, and of the bread, and to the somewhat close texture of the latter. other flours of lower percentages of nitrogenous compounds have, notwithstanding this great "*strength*," a higher character when used alone for bread-making purposes. These highly nitrogenous wheats are chiefly imported from Russia, and independently of a high ripening temperature, they are for the most part grown on very rich soil, and sown in the Spring. On this point it is worthy of notice, that home-grown Spring wheat, has sometimes the character of imparting strength to the flour of an inferior Winter wheat, and in the only instance of this kind which we have examined, the reputed stronger (Spring) wheat, had the higher percentage of nitrogen.

It may be stated generally, that the highly nitrogenous foreign wheats, have the admitted character of imparting strength to inferior flour; and they are thus highly valued for the purpose of admixture with home-grown grain imperfectly developed and matured. These highly nitrogenous imported wheats have, as the rule, been matured under a much higher temperature than our own; their nitrogenous constituents would appear to be in larger *proportion* in the form of gluten; and it is in wheats so ripened,

iat the higher percentage of fatty matter is also found, the proper lending of which, according to the experiments of Peligot, consi-erably affects the physical characters of the gluten. The opinion f Peligot—indeed of other recent investigators, and in this we fully oncur—is, that the measure of value of different flours for the pur-oses of bread-making, is certainly much more dependent on the *con-lition* of their constituents, than on their mere percentage amount of iitrogenous compounds. This high *condition* of the nitrogenous, and also the other compounds, would seem to be alike possible in wheats of high and of somewhat low percentage of nitrogen—pro-vided, other things being equal, they have been well developed, and ripened at a high temperature; whilst, when this is so, an undoubted preference is given to the less nitrogenous grains. This is partly lue to the latter being generally softer, and more amenable to cur-ent milling methods; and partly to the widely-differing structural aracter of the farinal matter, by virtue of which the flour not ly makes a better and more workable dough, but the bread oduced is of superior texture and lightness—conditions which analogy would lead us to conclude, must materially aid its gestion and assimilation, and consequently so far increase its lue as food.

A high percentage of nitrogenous compounds, provided the ain be well-developed and matured, and not so hard as to offer echanical obstacles to fine division and easy separation of the an in the mill, will tend to a great weight of bread, and a good ality as to texture. It would appear, however, that a smaller rcentage, if with equally high elaboration, will tend to a similar sult as to weight, and to even higher qualities as to texture id whiteness. Within the limits of our own island, however, on ie average of seasons, the better-elaborated grain will probably the less nitrogenous,* though the nitrogenous matter it does ntain, will be in a high condition as to elaboration, and to its utual relations, structural and chemical, with the other consti-ents of the flour. Hence it comes to pass that, as our home-own flours go, those which are the best in the view of the baker, ill frequently be those having a low *percentage* of nitrogenous mpounds—a higher *condition* more than compensating for the

* This is, however, not always the case; and, had we extended our review beyond ie ten years to which Tables I and III refer, we should have found, in the season of 855, both high development and maturation of grain, and high percentage of nitro-enous compounds. Of the cases included in our survey, the season of 1847, af-orded in the highest degree the combination of characters here referred to.

higher percentage of nitrogen, generally associated as it is in our climate, with an inferior degree of development and maturation.

We conclude, then, that condition of *maturation*, or perhaps rather *elaboration*, as well as mere percentage composition, should be theoretically, as it is practically, admitted as an essential element in estimating the relative qualities of different wheats or flours, for bread-making purposes. The opinions of some of the most recent, and perhaps the most competent observers, certainly point in the same direction as the one here indicated. Still, the current opinion derived from several of our standard works, would seem to be, that a high percentage of nitrogenous compounds should be taken as an almost unconditional measure of value.

But besides the frequently reiterated statement that the baker's estimate is founded on the amount of the gluten, it is also pretty generally maintained, that it is the amount of this, or of the nitrogenous constituents collectively, which determines the comparative values of different flours or breads, to the *consumer*. With regard to those foreign wheats which have their nitrogenous substance in a highly-elaborated condition, and favourably related to the other matters, and in which the whole is structurally fitted for easy milling, and to yield a light and easily-digestible bread, we would not say that, with such, a comparatively high *percentage* also of the nitrogen, might not be an additional point of value. But, even with the foreign wheats, it is but a small proportion that combine these several qualities; whilst those which have the most of the others, have, generally, less of the *amount* of nitrogenous substance. With home-grown wheats, too, as already said, information at present at command tends to show, that high percentage of nitrogen is, frequently at least, associated with *low condition of elaboration* of the constituents of the grain, yielding an inferior bread-flour—and thus, though from opposite causes to those which depreciate the richer nitrogenous grains of the higher-ripening temperatures, a less valuable food.

Let it be conceded, then, that condition, or elaboration, must affect the digestibility and assimilability of our food. But, we think it may be inferred, yet on other grounds, *that, as flours go*, the richer in the more directly respirable and fat-forming compounds, will generally be more valued as food.* The following Table (for

* There is experimental evidence to show, that the nitrogenous constituents of food may serve one or both of these offices; but, when in excess, probably at a greater cost to the system.

of the data of which we are indebted to Dr. Playfair), g the estimated average percentage of nitrogen and of car- a number of standard articles of food, and also the rela- them of the one constituent to the other, will aid us in ting our meaning :—

TABLE XV.

mated Average Composition of Standard Articles of Food.

Foods.	Per Cent.			Nitrogen to 100 Carbon.
	Dry Substance.	Carbon.	Nitrogen.	
esh)	45·0	30·0	2·0	6·6
green)	80 0	57 0	1·13	2·0
ried)	85·0	61·0	1·4	2·3
Butter	85·0	68·0	0 0	
... ...	10.0	5·4	0·5	9 ·3
... ...	60·0	36·0	4 5	12·5
wheaten)	85·0	38·0	1·72	4·5
... ...	64·0	28·5	1·29	4·5
... ...	87·0	40·0	1·75	4·4
... ...	85 0	40 0	2 0*	5·0
... ...	87 0	39·0	1·0	2·56
... ...	25·0	11 0	0·35	3·2
les (succulent, average) ...	15·0	6·0	0 2	3·3
... ...	85·0	39·0	3·65	9·4
... ...	95·0	40·0	0·0	
id Chocolate	92·0	56·2	2 0	3·6
Porter	9·5	4·5	0·01	0·2

this Table it is seen, that wheaten flour and bread contain as proportion of nitrogen to carbon as most of the current of food of our working population, excepting the important of fresh meat, milk, and cheese. Were we to ask, to what articles the working man next resorts, when his means allow add other foods to his main diet of bread?—the answer be, cheese, bacon, and, perhaps, butter; and we think it further be, that his preference would generally be for the The Table shows that, so far as he took cheese, he would erably increase the proportion of the nitrogen to the carbon consumed. The amount of it he would eat would, however, than that of bacon, and in the latter he would only con- half as much nitrogen, in proportion to the carbon, as he in bread alone. In *fat*, or butter, he would have no nitrogen.

* *Scotch oatmeal* would range higher than this.

at all, so that the addition of either of these to his flour or bread would still further reduce the proportion of nitrogen to carbon in his food. But all these substances, besides their respirable carbon, have a large proportion of respirable hydrogen, due to their *fat or substance*. Even cheese, which contains the least amount of this, has, nevertheless, a very considerable percentage of it; bacon much more; whilst fat and butter, excluding their water, are, of course, wholly composed of it. If, therefore, we take into calculation the respirable hydrogen, it will be seen that the *respiratory capacity* (so to speak) of the cheese, would be much higher relatively to the *flesh-forming*, than the relation to the carbon alone, as in the Table, would indicate. In the bacon, on the other hand, the relation even of the carbon alone to the nitrogen, is much greater than in bread; and, if we further take into account its respirable hydrogen, its respiratory, relatively to its flesh-forming capacity, will appear still greater in comparison with the bread. Lastly, even taking the case of fresh meat, so large is its amount of fat, and, therefore, of respirable hydrogen, that its respiratory and fat-forming, relatively to its flesh-forming capacity, would be much higher, as compared with bread, than the figures in the Table, relating to carbon alone, would show.

From these considerations we think it may fairly be concluded, that the first more urgent call of the system of our under-fed, or only bread-fed, working man, is for an increased supply of respiratory or fat-forming, rather than of flesh-forming, constituents of food. Indeed it is to *fat itself*, in some form, that he first resorts.

If, then, the first demand of the system be generally for more of the more directly respirable or fat-forming material, than bread alone supplies:—if the foreign wheats of more than average percentage of nitrogen have, frequently, structural characters which render them with greater difficulty made into an easily-digestible bread:—if the more highly-nitrogenous wheats of our colder summers have their constituents frequently in a less highly-elaborated condition:—and if, finally, the introduction of more of the nitrogenous constituents of our grain into the bread-flour, generally introduces at the same time branny particles which cause the food to pass in too large a proportion undigested from the body—it would appear, that the standard of value of food-stuffs as they go, according to their nitrogenous percentage, is, at least, only conditionally correct, and that the current views on the point require to be somewhat modified.

From all the data at our command we have adopted 1·29 as the *probable* average percentage of nitrogen in wheaten bread. That

Dr. Maclagan is from 1·1 to 1·2; and that by Playfair n about 1·1. These amounts represent respectively about l 7 of nitrogenous compounds.* It will not be sup-, because, from the facts adduced, we are led to believe ldition to such a bread as is here assumed, the first call em of the working man would be for more of respiratory rming material, we would therefore deny the advantage ased supply of nitrogenous constituents also. We would, ubmit, as worthy of reflection, that, whilst the relation n to 100 of carbon in wheaten flour and bread is 4·5, average of the food consumed, taking eighty-six cases, to fifteen classes, and including both sexes and all ages, ·34. These dietaries included many which were exceed-al, so far as the nitrogen supplied was concerned; yet a nsideration of their details showed that, taking into their respirable hydrogen, the relation of purely respi-fat-forming, to flesh-forming material, in most of these dietaries, would be nearly as great in bread. Indeed, ppear that, that which is admitted to be a superior class distinguished much more by including a certain amount portant non-nitrogenous constituents, in the condition, of concentration, as in fatty matter—and of the nitro-es, in the high condition, as in animal food, than by proportion of its flesh-forming to its more exclusively and fat-forming constituents.

Appendix.

assumption that it is established by others (for we have ves any direct experiments on the point), that the loss of nce, by the panary fermentation, is less than one, and, ss than 0·5 per cent. of that of the flour employed, it is at the number of loaves of a given weight obtained from flour (280 lbs.) being given, and the percentage of e flour also known, we could easily estimate, within very its, the percentage of dry substance in the bread produced. ntage of dry matter in bread, thus determined by calcu-the actual or assumed amount in the flour, will be too

timates have reference to the bread from rather fine flour; that from the s contains rather more of nitrogenous matters.

high by the unknown quantity lost by fermentation, and too low by the amount of salt, or other saline matter, added. On the latter point it may be stated, that about 4 lbs. of salt to the sack of flour is equal to about 1 per cent. in the bread. Indeed, assuming the loss by fermentation as above, and taking such data as we possess as to the usual amount of mineral matter added by the baker, we are disposed to conclude, that the dry matter in bread, calculated as above supposed from the amount of dry substance in flour, and the amount of bread it yields, would be too low by from 0·5 -1 per cent., depending on the quantity of the extraneous mineral matter used.

Again, if the whole of the loss by the changes during fermentation be less than 0·5 per cent., and if these, as is known to be the case, mainly affect the non-nitrogenous constituents, we can, in the same way as for the dry matter and the water, estimate pretty exactly the amount of *nitrogen*, or of *nitrogenous compounds*, from the amount of the one or the other in the flour employed.

Frequently, however, the estimates which are given by one and the same authority, for the composition of wheaten-flour and bread respectively, do not seem to bear a proper relation to each other. We have thought, therefore, that it might be useful to give, as an appendix to our paper, a tabular form, showing the yield of bread from 100 of flour, and the percentages of dry matter, water, nitrogen, or nitrogenous compounds, in the former—assuming any given number of four-pound loaves to be obtained from a sack of flour, and assuming also given probable amounts of water and of nitrogen in the flour. This is accordingly done in Table XVI, which follows.

We need only further say that, with fermented baker's bread of good quality, ninety-five *really four-pound loaves* to the sack of flour, is a yield perhaps very seldom reached.* It would appear, however, from published statements, that of unfermented bread, more than 100 four-pound loaves may be obtained from the sack of flour. It is worthy of remark, that if this be the case, and if the loss by the fermentative process be really so small as is now supposed, the gain in weight by the non-fermenting method, is only a gain of *water retained in the bread*. Unless, therefore, the unfermented bread be better adapted for digestion or assimilation, or be sold at a correspondingly lower price, the consumer will be a considerable loser by the purchase of the unfermented loaf.

* We speak of course of *pure wheaten bread*.

TABLE XVI.

Showing the Composition of Wheaten Bread, calculated from the Quantity of Bread obtained from a given Weight of Flour, and from the Composition of the Flour.*

Number of 4-lb. Loaves obtained from a Sack (280 lbs.) of Flour.	Equal to Bread for 100 Flour.	Per Cent. Dry Matter and Water in the Bread.						Per Cent. Nitrogen, or Nitrogenous Compounds (Gluten, Albumen, &c.), in Bread. (Nitrogenous Compounds = Nitrogen × 6·3).							
		If 16 per Cent. Water in Flour.		If 15 per Cent. Water in Flour.		If 14 per Cent. Water in Flour.		If 1·65 Nitrogen (=10·4 Nit. Compound) per Cent. in Flour.		If 1·7 Nitrogen (=10·7 Nit. Compound) per Cent. in Flour.		If 1·75 Nitrogen (=11·0 Nit. Compound) per Cent. in Flour.		If 1·8 Nitrogen (=11·3 Nit. Compound) per Cent. in Flour.	
		Dry Matter in Bread.	Water in Bread.	Dry Matter in Bread.	Water in Bread.	Dry Matter in Bread.	Water in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.
90	128·6	65·3	34·7	66·1	33·9	66·9	33·1	1·28	8·06	1·32	8·32	1·36	8·57	1·40	8·82
91	130·0	64·6	35·4	65·4	34·6	66·1	33·9	1·26	7·94	1·31	8·25	1·35	8·50	1·38	8·69
92	131·4	63·9	36·1	64·7	35·3	65·4	34·6	1·25	7·87	1·29	8·13	1·33	8·38	1·37	8·63
93	132·8	63·2	36·8	64·0	36·0	64·7	35·3	1·24	7·81	1·28	8·06	1·32	8·32	1·35	8·50
94	134·3	62·5	37·5	63·3	36·7	64·0	36·0	1·23	7·75	1·26	7·94	1·30	8·19	1·34	8·44
95	135·7	61·9	38·1	62·6	37·4	63·4	36·6	1·22	7·69	1·25	7·87	1·29	8·13	1·33	8·38
96	137·1	61·3	38·7	62·0	38·0	62·7	37·3	1·20	7·56	1·24	7·81	1·28	8·06	1·31	8·25
97	138·6	60·6	39·4	61·3	38·7	62·0	38·0	1·19	7·50	1·23	7·75	1·26	7·94	1·30	8·19
98	140·0	60·0	40·0	60·7	39·3	61·4	38·6	1·18	7·43	1·21	7·62	1·25	7·87	1·29	8·13
99	141·4	59·4	40·6	60·1	39·9	60·8	39·2	1·17	7·37	1·20	7·56	1·24	7·81	1·27	8·00
100	142·8	58·8	41·2	59·5	40·5	60·2	39·8	1·15	7·24	1·19	7·50	1·22	7·69	1·26	7·94
101	144·3	58·2	41·8	58·9	41·1	59·6	40·4	1·14	7·18	1·18	7·43	1·21	7·62	1·25	7·87
102	145·7	57·6	42·4	58·3	41·7	59·0	41·0	1·13	7·12	1·17	7·37	1·20	7·56	1·23	7·75
103	147·1	57·1	42·9	57·8	42·2	58·5	41·5	1·12	7·05	1·15	7·24	1·19	7·50	1·22	7·69
104	148·6	56·5	43·5	57·2	42·8	57·9	42·1	1·11	6·99	1·14	7·18	1·18	7·43	1·21	7·62
105	150·0	56·0	44·0	56·7	43·3	57·3	42·7	1·10	6·93	1·13	7·12	1·17	7·37	1·20	7·56

* The Figures in the Table should, of course, be taken subject to the qualifying remarks which have been made. It is obvious that the form can easily be extended to include any further or intermediate ranges of produce of Bread, or composition of Flour.



AGRICULTURAL CHEMISTRY.

ON THE

GROWTH OF BARLEY

BY

DIFFERENT MANURES,

CONTINUOUSLY ON THE SAME LAND;

AND ON

THE POSITION OF THE CROP IN ROTATION.

BY

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AND

DR. J. H. GILBERT, F.C.S.

FROM THE JOURNAL OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND,
VOL. XVIII., PART II.,
1857;
WITH SUPPLEMENTARY RESULTS IN TABLES XVI., XVII., AND XVIII.; AND
SOME ALTERATIONS OF THE SUCCEEDING TEXT ACCORDINGLY,
1858.

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ON THE GROWTH OF BARLEY BY DIFFERENT MANURES, &c.

In endeavouring in former Papers in the Journal of the Royal Agricultural Society to convey such an idea as existing knowledge permitted, of the chemical facts and principles which our *Rotation of Crops* involves, we have supported the views put forth, by carefully ascertained data regarding the individual elements which constitute that important practice. The subjects which necessarily pass under review in such an inquiry are, the characteristic requirements of growth of—

1st. The Root Crops,

2nd. The saleable Cereal Grains,

3rd. The Leguminous Corn and Fodder Crops;

and lastly, the chemical circumstances involved in—

4th. The consumption of food by stock on the farm.

In regard to some of these branches, only the general conclusions drawn from the evidence accumulated have been given: whilst on others, a good deal of the evidence upon which the conclusions have been founded, has been laid in detail before the reader.

Thus, with regard to the *Cereals*, the reader is already in possession of a considerable portion of the results of the experiments in the *field** relating to the growth of *wheat;* and before adding to the registry on that head, it seems desirable to put on record something relating to *barley*—the next in importance to wheat in the class of the saleable cereal grains of our rotations.

We have always assumed that barley, apart from local and minor distinctions, was closely allied to wheat in certain characteristic chemical requirements of its growth. Independently of common observation, the direct evidence upon which this opinion was founded, was a course of field experiments on barley, conducted in 1845. At that time about ten acres were appropriated to the investigation, which it was intended should be continued through a considerable series of years. Owing, however, to the great labour and attention required in following up experiments of this kind, both in field and laboratory, with sufficient accuracy and detail to serve a scientific purpose, it was decided to rest satisfied with the first year's clear indications in the field, until other branches of the main inquiry, then occupying all our available time, should be somewhat further forwarded.

* For the results in the *laboratory*, showing the influence of circumstances of growth on the *composition* of wheat, see 'Journal of the Chemical Society,' vol. x., part i., p. 1-55: 'On some points in the Composition of Wheat-Grain, its Products in the Mill, and Bread.'

.c experiments with barley grown by different manures
ıed in 1852. It is the field results of these from
o the present, together with some gleanings from the
relating to them, and also the records of collateral
ı on the crop grown under certain other known con-
nanuring and cropping, and in rotation, that will form
; of the present Paper. On this plan our tabulated
l be necessarily very voluminous. It would be un-
herefore, to encumber our statement with a detailed
the earlier series of experiments, especially as the
though not quite so comprehensive, are somewhat
nged for showing up the points of interest. It will
ay then, of the earlier experiments, that their results
stent with those of the later, which are now to be

l set apart in 1852 for the continuous growth of barley
; manures was in the adjoining field to that devoted to
ous growth of wheat, and its general character was very
hat of the latter. It had grown clover in 1849, wheat in
in 1851 barley, dressed with sulphate of ammonia. It
ore, in an agricultural point of view, in a somewhat
condition so far as the aftergrowth of grain was con-
it was hence in a suitable state for testing the effects
t manures upon the barley crop. The area of land
d was about five acres, divided into nearly square plots
ne-fifth of an acre each. In order to distinguish this
riments from those afterwards to be noticed, it will be
to give the field in which it was made its usual name,
ɔos-field.
:ription and quantities of the different manures are given
space will permit, in the Tables, by the side of the
y yielded. To the statements there given one or two
s will be necessary.
l be mentioned, that there were two plots unmanured,
ıer side of the experimental land; and it is the mean
ıese that is given as Experiment No. 1.
r and weed-ashes employed in Experiment No. 2, were
ıe description as those mixed in smaller quantity with
ıanures to aid their easy distribution over the land.
nyard manure, was only from the open yard, and did
the dung of animals highly fed on artificial food.

alled "*Mixed Alkalies*," comprised, per acre—

300 lbs. sulphate of potash,
200 lbs. sulphate of soda,
100 lbs. sulphate of magnesia.

The "*Superphosphate of Lime*," was composed (per acre) of—

200 lbs. calcined bone-dust,
150 lbs. sulphuric acid (sp. gr. 1·7).

The "*Mixed Minerals*," consisted of both the "Mixed Alkalies," and the "Superphosphate of Lime," as above described.

All the artificial manures, after being well mixed with clay and weed-ashes up to a given measure, were carefully sown by *hand*; for, though the drill is undoubtedly by far the best means of getting an average distribution of manure over large areas of land, the experience of our wheat experiments has taught us that there is danger of some irregularity when applied only to small ones, where accuracy, one compared with another, is essential. The manures being sown, they were ploughed in very shallow.

The seed, which was the Chevalier, was however always *drilled*—2½ bushels per acre in 1852 and 1853, and 7 pecks per acre in 1854-5-6 and 7.

The results obtained during the six years' continuance of the experiments are given in Tables as follows :—

Table I.—Dressed Corn per Acre, in bushels and pecks.
Table II.—Total Corn per Acre, lbs.
Table III.—Total Straw and Chaff per Acre, lbs.
Table IV.—Total Produce (Corn and Straw together) per Acre, lbs.
Table V.—Proportion of Total Corn, in 100 Total Produce.
Table VI.—Proportion of Dressed Corn, in 100 Total Corn.
Table VII.—Weight per Bushel of Dressed Corn, lbs. and tenths.

Table VIII. is a summary of Tables I. to VII. inclusive. It gives, for each separate year, the seven characters of crop which the former Tables respectively record, but for the *mean only* of five classes, into which the series of individual experiments are here arranged. This Table affords, therefore, at one view a comparison of the effects of the individual *seasons* (both upon the quantity and quality of the produce); and each under the influence of five distinct classes of manures.

Table IX. is a summary of another kind. It gives for each of the twenty individual manures its *average annual* effect, taken over six years, on each of the characters of quality and quantity of the produce. In this Table, therefore, instead of comparing the influence of the individual *seasons*, we compare that of the individual *manures*, taking for each the mean result of six years' trial. (For the Tables I.-IX. inclusive, see pp. 6-23.)

It would be only irksome to the reader, and perhaps even confusing, were we to give a running and detailed comment upon the numerous figures recorded in Tables I. to VII. They are, however, deserving a careful examination, which cannot fail usefully to fix on the mind the clear idea which actually recorded facts conveys, of how really great are the fluctuations in the results of the farmer's efforts and outlays, due to the ever-changing seasons. Such a study would at the same time show, that, however great the uncertainty as to the actual amounts of produce to be calculated upon, depending upon climatic vicissitudes, there is still, even with these, on some points a considerable degree of uniformity and certainty in the relative results of certain characteristic classes of manures. In the comments which follow we shall confine attention chiefly to the Summary Tables VIII. and IX. In doing so we shall perhaps be able to convey a sufficient idea of the prominent results to the casual reader, and at the same time usefully to guide the further examination of the more careful one.

It would have been a useful introduction to the consideration of the actual variations of results obtained in the field in the different seasons, to have taken a comparative view in some detail, of the climatic conditions themselves of the six seasons under which the varying results have been obtained. With the view of doing this, numerous tables have been arranged, bringing together in much detail the actual climatic statistics of the several seasons; and also others, showing the indices or relative order, comparing season with season, of the actual characters so registered. From the large amount of tabular matter, and the space required for its consideration, which the more proper subject matter of the paper—the effects of different manures on the barley crop—itself involves, we are obliged to forego this part of our plan. A few general observations must suffice therefore, on this intimately associated collateral branch of the subject. When, however, it is considered, that the different seasons will vary almost infinitely in relation to one another in their favourable adaptations at each succeeding period of their advance, and that with these variations must vary as constantly the tendency of development of the plant for quantity or for quality, it will be obvious, that it is only a very detailed consideration of climatic statistics, taken together with careful coincident observation in the field, that can afford a really clear perception of the connection of the ever fluctuating characters of season, with the equally fluctuating characters of result. It is in fact the distribution, and the mutual adaptations, of the many characters making up the season, in their relation to the stage of growth of the plant, which give the resultant impress, for quantity or for quality, upon its progress.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:—[illegible]
(Hoos-Fie

TABLE II.—TOTAL CO[illegible]

Experiments.	MANURES. (Quantities per Acre, per Annum).	ASH[illegible]			
		1852.	1853.	1854.	185[illegible]
	SERIES 1.—Gauge.				
1	No Manure	lbs. 1600	lbs. 1588	lbs. 1578	lbs. [illegible]
2	20 bushels Clay and Weed Ashes	1451	1655	1901	[illegible]
	Mean	1526	1547	1740	[illegible]
3	14 tons Farmyard Manure	1944	21.95	3127	[illegible]
	SERIES 2.—W[illegible]				
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	1558	1586	2021	[illegible]
5	Superphosphate of Lime	1605	1867	2298	[illegible]
6	Superphosphate of Lime, and "Mixed Alkalies"	1819	2017	2571	[illegible]
	Mean	1661	1823	2231	[illegible]
	SERIES 3.—With Nitrogen per acre, equal to about [illegible]				
7	275 lbs. Nitrate of Soda, alone	*	2044	2740	[illegible]
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	2086	2265	2763	[illegible]
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2091	2259	2697	[illegible]
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	2212	2452	3167	[illegible]
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	2268	2809	3429	[illegible]
	Mean	2190	2502	3063	[illegible]
	SERIES 4.—With Nitrogen per acre, equal to about [illegible]				
12	550 lbs. Nitrate of Soda, alone	*	2071	3113	[illegible]
13	200 lbs. each Sulphate and Muriate of Ammonia, alone	2486	2894	3918	[illegible]
14	3000 lbs. Rape Cake, alone	2188	2818	3888	[illegible]
15	200 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2431	2854	3975	[illegible]
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	2468	2835	3648	[illegible]
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	2589	3080	3859	[illegible]
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	1907	2113	3021	[illegible]
19	2000 lbs. Rape Cake, and Superphosphate of Lime	2057	2343	3444	[illegible]
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	2098	2402	3413	[illegible]
	Mean	2278	2814	3680	[illegible]

* No Nitrate of Soda in 1852; but Sulphate of Potass, and Superphosphate of Lime.

consecutive Years on the same land—1852, 53, 54, 55, 56, and 1857.
, Herts.)
in Lbs.

7.	Total (6 years).	Average. Annual.	Average Annual Increase by Manure.	
				With what Standard compared.
s.				
0	lbs. 9,469	lbs. 1578	lbs.	
9	9,554	1592		
9	9,512	1585		
5	14,448	2407	822	Over Unmanured.
res, only.				
1	9,760	1627	42	Over Unmanured.
3	10,490	1748	163	Over Unmanured.
1	11,486	1914	329	Over Unmanured.
1	10,579	1763	178	Over Unmanured.
th without and with direct Mineral Manures.				
4	†11,820	†2364	779	Over Unmanured.
8	13,144	2191	606	Over Unmanured.
2	13,680	2272	645	Over "Mixed Alkalies" (No. 4).
1	15,268	2545	797	Over Superphosphate of Lime (No. 5).
6	15,579	2596	682	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
0	14,336	2304	631	Over Mean of Mineral Series.
th without and with direct Mineral Manures.				
6	† 13,331	†2666	1081	Over Unmanured.
5	15,619	2603	1018	Over Unmanured.
7	15,984	2664	1079	Over Unmanured.
8	14,647	2441	814	Over "Mixed Alkalies" (No. 4).
6	16,651	2775	1027	Over Superphosphate of Lime (No. 5).
7	16,806	2801	867	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
7	15,028	2505	878	Over "Mixed Alkalies" (No. 4).
1	16,088	2678	925	Over Superphosphate of Lime (No. 5).
6	15,978	2662	748	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
9	15,816	2643	880	Over Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:—made (Hoos-Field,

TABLE III.—TOTAL STRAW, and

Experiments.	MANURES. (Quantities per Acre, per Annum.)	ANNUAL			
		1852.	1853.	1854.	1855.
	SERIES 1.—Gauge, or				
1	No Manure	lbs. 1884	lbs. 1959	lbs. 2479	lbs. [illegible]
2	20 bushels Clay and Weed Ashes	1579	1741	2017	[illegible]
	Mean	1731	1865	2295	[illegible]
3	14 tons Farmyard Manure	3076	2546	4171	[illegible]
	SERIES 2.—With				
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	1847	1985	2882	[illegible]
5	Superphosphate of Lime	1854	1916	2600	[illegible]
6	Superphosphate of Lime and "Mixed Alkalies"	2189	2288	2526	[illegible]
	Mean	1963	2049	2559	[illegible]
	SERIES 3.—With Nitrogen per acre, equal to about 50 lbs.				
7	275 lbs. Nitrate of Soda, alone	*	2587	3785	[illegible]
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	2564	2965	3891	[illegible]
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2639	3020	3774	[illegible]
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	2915	2950	4580	[illegible]
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	3119	2975	4430	[illegible]
	Mean	2909	2779	4009	[illegible]
	SERIES 4.—With Nitrogen per acre, equal to about 100 lbs.				
12	550 lbs. Nitrate of Soda, alone	*	2985	4297	[illegible]
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	3004	3390	4888	[illegible]
14	2000 lbs. Rape Cake, alone	2756	3005	4892	[illegible]
15	200 lbs. each Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2947	3047	4340	[illegible]
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	3179	3190	4976	[illegible]
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	3182	3344	5487	[illegible]
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	2444	2980	4027	[illegible]
19	2000 lbs. Rape Cake, and Superphosphate of Lime	2656	2967	4944	[illegible]
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	2698	3084	4713	[illegible]
	Mean	2868	3086	4706	[illegible]

* No Nitrate of Soda in 1852 but Sulphate of Potass, and Superphosphate of Lime.

six consecutive Years on the same Land—1852, 53, 54, 55, 56, and
ested, Herts.)

per ACRE—in lbs.

CE.	TOTAL (6 years)	Average Annual.	Average Annual Increase by Manure.	
1857.				With what Standard compared.
l Series.				
lbs. 1570 1637	lbs. 10,875 10,947	lbs. 1812 1708	lbs.	
1604	10,561	1760		
2649	16,789	2790	1060	Over Unmanured.
Manures, only.				
1695	10,779	1796	36	Over Unmanured.
1745	11,076	1846	66	Over Unmanured.
1920	12,071	2012	252	Over Unmanured.
1788	11,809	1695	125	Over Unmanured.
a; both without and with direct Mineral Manures.				
2755	†14,809	†2802	1102	Over Unmanured.
1986	15,226	2598	778	Over Unmanured.
2400	16,706	2784	988	Over "Mixed Alkalies" (No. 4).
3000	19,042	3174	1828	Over Superphosphate of Lime (No. 5).
3120	19,601	3267	1255	Over Superphosphate of Lime, and "Mixed Alkalies"
2652	17,586	2926	1040	Over Mean of Mineral Series.
nia; both without and with direct Mineral Manures.				
3580	†17,657	†3582	1772	Over Unmanured.
2695	19,146	3191	1481	Over Unmanured.
3715	21,288	3548	1786	Over Unmanured.
2910	19,871	3312	1516	Over "Mixed Alkalies" (No. 4).
3687	22,898	3815	1969	Over Superphosphate of Lime (No. 5).
4057	24,486	4078	2061	Over Superphosphate of Lime, and "Mixed Alkalis
3460	20,840	3390	1594	Over "Mixed Alkalies" (No. 4).
3745	21,790	3632	1786	Over Superphosphate of Lime (No. 5).
3705	21,925	3688	1936	Over Superphosphate of Lime, and "Mixed Alkali
3600	21,344	3570	1695	Over Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:—(Hoos-Fie

TABLE III.—TOTAL STRAW,

Experiments.	MANURES. (Quantities per Acre, per Annum).	ASH			
		1852.	1853.	1854.	18
	SERIES 1.—Gauge				
1	No Manure	lbs. 1844	lbs. 1950	lbs. 3472	
2	20 bushels Clay and Weed Ashes	1579	1761	2817	
	Mean	1711	1855	3144	
3	14 tons Farmyard Manure	3076	2746	4171	
	SERIES 2.—				
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	1847	1985	2852	
5	Superphosphate of Lime	1854	1916	2900	
6	Superphosphate of Lime and "Mixed Alkalies"	2189	2285	3216	
	Mean	1963	2049	2989	
	SERIES 3—With Nitrogen per acre, equal to about 5				
7	275 lbs. Nitrate of Soda, alone	*	2597	3775	
8	180 lbs. each, Sulphate and Muriate of Ammonia, alone	2564	2965	3892	
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2689	2980	3775	
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	2915	2980	4580	
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	3119	2975	4530	
	Mean	2809	2779	4008	
	SERIES 4—With Nitrogen per acre, equal to about 10				
12	550 lbs. Nitrate of Soda, alone	*	2486	4207	
13	360 lbs. each, Sulphate and Muriate of Ammonia, alone	3004	2980	4586	
14	2000 lbs. Rape Cake, alone	2756	3005	4460	
15	200 lbs. each Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	2947	3047	4340	
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	3179	3180	4976	
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	3182	3344	5197	
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	2444	2980	4627	
19	2000 lbs. Rape Cake, and Superphosphate of Lime	2886	2987	4944	
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	2994	3094	4713	
	Mean	2948	3086	4705	

* No Nitrate of Soda in 1852 but Sulphate of Potass, and Superphosphate of Lime.

x consecutive Years on the same Land—1852, 53, 54, 55, 56, and 1857.
ted, Herts.)
er ACRE—in lbs.

1857.	TOTAL (6 years)	Average Annual.	Average Annual Increase by Manure.	
				With what Standard compared.
eries.				
lbs. 1570	lbs. 10,875	lbs. 1812	lbs.	
1687	10,347	1708		
1604	10,561	1760		
2649	16,789	2790	1060	Over Unmanured.
anures, only.				
1685	10,779	1796	86	Over Unmanured.
1745	11,076	1846	86	Over Unmanured.
1920	12,071	2012	262	Over Unmanured.
1788	11,809	1985	125	Over Unmanured.
both without and with direct Mineral Manures.				
2755	†14,809	†2663	1102	Over Unmanured.
1985	15,236	2538	778	Over Unmanured.
2400	16,706	2784	988	Over "Mixed Alkalies" (No. 4).
3000	19,042	3174	1826	Over Superphosphate of Lime (No. 5).
3120	19,601	3267	1955	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6.).
2662	17,588	2925	1040	Over Mean of Mineral Series.
; both without and with direct Mineral Manures.				
3690	†17,557	†3582	1772	Over Unmanured.
2885	19,146	3191	1481	Over Unmanured.
3715	21,398	3548	1788	Over Unmanured.
2910	19,871	3312	1516	Over "Mixed Alkalies" (No. 4).
3687	22,898	3815	1969	Over Superphosphate of Lime (No. 5).
4057	24,498	4073	2061	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
3460	20,340	3390	1594	Over "Mixed Alkalies" (No. 4).
3745	21,790	3632	1786	Over Superphosphate of Lime (No. 5).
3708	21,935	3688	1696	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
3600	21,344	3570	1685	Over Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different

TABLE IV.—TOTAL

Experiments.	MANURES. (Quantities per Acre, per Annum.)	1852.	18
			SER
1	No Manure	lbs. 3484	1
2	20 bushels Clay and Weed Ashes	3080	2
	Mean	3257	2
3	14 tons Farmyard Manure	3920	4
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	3405	3
5	Superphosphate of Lime	3450	3
6	Superphosphate of Lime, and "Mixed Alkalies"	4008	4
	Mean	3621	3
	SERIES 3.—With Nitrogen per acre, eq		
7	275 lbs. Nitrate of Soda, alone	*	4
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	4053	4
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	4780	5
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	5127	5
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	5467	5
	Mean	4999	5
	SERIES 4.—With Nitrogen per acre, equ		
12	550 lbs. Nitrate of Soda, alone	*	4
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	5490	5
14	2000 lbs. Rape-Cake, alone	4949	5
15	300 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	5878	5
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	5668	5
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	5714	6
18	2000 lbs. Rape-Cake, and "Mixed Alkalies"	4361	4
19	2000 lbs. Rape-Cake, and Superphosphate of Lime	4713	5
20	2000 lbs. Rape-Cake, and Superphosphate of Lime, and "Mixed Alkalies"	4796	5
	Mean	5133	6

* No Nitrate of Soda in 1852; but Sulphate of Potass and Superphosphate of

six consecutive Years on the same Land—1852, 53, 54, 55, 56, and 1857.
nsted, Herts.)

RAW together), per ACRE—in Lbs.

E-	Total (6 years.)	Average Annual.	Average Annual Increase by Manure.	
1857.				With what Standard compared.
l Series.				
lbs. 5190	lbs. 20,344	lbs. 3391	lbs.	
3676	19,601	3300		
3398	20,078	3345		
5864	31,193	5197	1852	Over Unmanured.
Manures, only.				
3426	20,559	3426	78	Over Unmanured.
3606	21,566	3594	249	Over Unmanured.
4111	23,557	3926	581	Over Unmanured.
3714	21,867	3648	303	Over Unmanured.
l; both without and with direct Mineral Manures.				
3869	† 26,129	† 5226	1881	Over Unmanured.
4118	28,370	4729	1384	Over Unmanured.
4703	30,336	5056	1688	Over "Mixed Alkalies" (No. 4).
5161	34,310	5719	2125	Over Superphosphate of Lime (No. 5).
5805	35,180	5863	1987	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
5341	31,864	5319	1670	Over Mean of Mineral Series.
; both without and with direct Mineral Manures.				
3816	† 30,1[illegible]	† 6198	2853	Over Unmanured.
3360	34,765	5794	2449	Over Unmanured.
7302	37,272	6212	2867	Over Unmanured.
4518	34,518	5753	2330	Over "Mixed Alkalies" (No. 4).
3938	39,539	6590	2996	Over Superphosphate of Lime (No. 5).
7284	41,244	6874	2948	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
9277	35,368	5895	2472	Over "Mixed Alkalies" (No. 4).
3936	37,[illegible]28	6205	2711	Over Superphosphate of Lime (No. 5).
9341	37,798	6300	2374	Over Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
5340	37,162	6218	2565	Over Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:—m
(Hoos-Fie

TABLE V.—PROPORTION of TOT

Experiments	MANURES. (Quantities per acre, per Annum).	IN EA			
		1852.	1853.	1854.	185
	SERIES 1.—Gang				
1	No Manure	45·9	44·1	44·4	4
2	20 Bushels Clay and Weed Ashes	47·9	46·6	45·1	4
	Mean	46·9	45·4	44·8	4
3	14 tons Farmyard Manure	47·0	45·6	43·8	4
	SERIES 2.—1				
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	45·8	45·0	46·1	4
5	Superphosphate of Lime	46·4	49·8	46·9	4
6	Superphosphate of Lime, and "Mixed Alkalies"	45·4	46·8	47·8	4
	Mean	45·9	47·0	47·0	4
	SERIES 3.—With Nitrogen per acre, equal to about 4				
7	275 lbs. Nitrate of Soda, alone	*	44·1	42·3	4
8	100 lbs. each Sulphate and Muriate of Ammonia, alone	44·9	46·2	44·9	4
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	44·2	44·5	43·4	4
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	43·1	45·2	43·9	4
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	43·1	43·7	43·1	4
	Mean	43·8	44·7	43·3	4
	SERIES 4.—With Nitrogen per acre, equal to about 10				
12	550 lbs. Nitrate of Soda, alone	*	43·2	42·1	4
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	45·2	45·0	43·9	4
14	3000 lbs. Rape Cake alone	44·3	43·5	41·1	4
15	200 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	45·2	45·6	43·0	
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	43·8	43·4	42·3	
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	44·3	43·2	39·2	
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	43·6	42·7	41·9	
19	2000 lbs. Rape Cake, and Superphosphate of Lime	43·6	43·9	41·0	
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	43·7	43·7	43·0	
	Mean	44·1	43·2	41·6	

*No Nitrate of Soda in 1853; but Sulphate of Potass, and Superphosphate of Lime

g six consecutive Years on the same Land—1852, 53, 54, 55, 56, and 1857.
amsted, Herts.)

in 100 TOTAL PRODUCE.

AR.	Average Annual.	Difference according to Manure.	
1857.		Per Cent.	With what Standard compared.
rd Series.			
50·8	48·6		
51·5	48·2		
51·2	47·4		
47·8	45·5	1·9	Less than Unmanured.
l Manures, only.			
50·8	47·5	0·1	More than Unmanured.
51·6	48·6	1·2	More than Unmanured.
53·3	48·8	1·4	More than Unmanured.
51·9	48·3	0·9	More than Unmanured.
nia; both without and with direct Mineral Manures.			
48·9	† 45·2	2·2	Less than Unmanured.
51·8	46·8	1·1	Less than Unmanured.
49·0	45·0	2·5	Less than "Mixed Alkalies" (No. 4).
51·3	44·1	4·5	Less than Superphosphate of Lime (No. 5).
50·7	44·0	4·8	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
50·3	44·9	3·4	Less than Mean of Mineral Series.
nia; both without and with direct Mineral Manures.			
47·8	† 42·9	4·5	Less than Unmanured.
50·8	45·0	2·4	Less than Unmanured.
48·4	42·7	4·7	Less than Unmanured.
48·2	42·2	5·3	Less than "Mixed Alkalies" (No. 4).
50·1	41·7	6·9	Less than Superphosphate of Lime (No. 5).
47·5	40·6	8·2	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
49·7	42·8	5·2	Less than "Mixed Alkalies" (No. 4).
48·4	42·2	6·4	Less than Superphosphate of Lime (No. 5).
48·8	42·0	6·8	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
48·6	42·4	5·9	Less than Mean of Mineral Series.

† Taken for 5 Years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:— (Hoos-

TABLE VI.—PROPORTI

Experiments.	MANURES. (Quantities per Acre, per Annum.)	IN E			
		1852.	1853.	1854.	18
	SERIES 1.—Ger				
1	No Manure	90·8	86·1	94·6	
2	20 bushels Clay and Weed Ashes	91·9	89·6	93·7	
	Mean	91·3	87·9	94·2	
3	14 tons Farmyard Manure	94·5	87·4	97·2	
	SERIES 2.—				
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	89·3	90·5	96·8	
5	Superphosphate of Lime	93·8	94·8	95·6	
6	Superphosphate of Lime, and "Mixed Alkalies"	92·5	92·1	96·6	
	Mean	91·5	92·4	96·0	
	SERIES 3.— With Nitrogen per acre, equal to about				
7	275 lbs. Nitrate of Soda, alone	*	86·2	86·0	
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	89·6	88·9	92·7	
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	87·9	85·1	93·2	
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	89·2	89·6	95·6	
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	89·5	88·1	96·0	
	Mean	89·5	87·6	94·7	
	SERIES 4. With Nitrogen per acre, equal to about				
12	550 lbs. Nitrate of Soda, alone	*	89·0	90·8	
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	88·0	87·4	90·2	
14	2000 lbs. Rape Cake, alone	93·2	89·5	94·8	
15	200 lbs. each, Sulphate and Muriate of Ammonia and "Mixed Alkalies"	87·0	90·0	89·1	
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	87·5	89·7	91·0	
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	90·8	89·4	92·3	
18	2000 lbs. Rape-Cake, and "Mixed Alkalies"	90·0	86·0	92·8	
19	2000 lbs. Rape Cake, and Superphosphate of Lime	92·0	89·2	93·1	
20	2000 lbs. Rape-Cake, and Superphosphate of Lime, and "Mixed Alkalies"	89·1	89·0	93·3	
	Mean	90·0	87·8	91·9	

* No Nitrate of Soda in 1852; but Sulphate of Potash, and Superphosphate of Lime.

ecutive Years on the same Land—1852, 53, 54, 55, 56 and 1857, rts).

in 100 TOTAL CORN.

rage nual.	Difference according to Manure.	
	Per Cent.	With what Standard compared.
0·5		
2·0		
1·2		
8·7	2·5	More than Unmanured.
nly.		
2·4	1·2	More than Unmanured.
4·7	3·5	More than Unmanured.
4·1	2·9	More than Unmanured.
8·7	2·5	More than Unmanured.
ithout and with direct Mineral Manures.		
11·8	0·6	More than Unmanured.
10·8	0·4	Less than Unmanured.
10·6	1·8	Less than "Mixed Alkalies" (No. 4).
12·5	2·2	Less than Superphosphate of Lime (No. 5).
12·9	1·2	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
11·7	2·0	Less than Mean of Mineral Series.
ithout and with direct Mineral Manures.		
11·6	0·4	More than Unmanured.
10·6	1·6	Less than Unmanured.
12·4	1·2	More than Unmanured.
39·1	3·3	Less than "Mixed Alkalies" (No. 4).
10·6	4·1	Less than Superphosphate of Lime (No. 5).
11·8	2·3	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
32·0	0·4	Less than "Mixed Alkalies" (No. 4).
91·4	3·3	Less than Superphosphate of Lime (No. 5).
91·7	2·4	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
91·1	2·6	Less than Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:—I
(Hook F

TABLE VII.—WEIGHT per Bu

Experiments.	MANURES. (Quantities per Acre, per Annum.)	1852.	1853.	1854.
				SERIES 1.—(
1	No Manure	52·1	50·8	53·1
2	20 bushels Clay and Weed Ashes	53·0	50·9	55·6
	Mean	52·6	50·9	55·4
3	14 tons Farmyard Manure	52·7	51·6	58·9
				SERIE
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	52·5	51·9	58·6
5	Superphosphate of Lime	52·6	52·6	54·0
6	Superphosphate of Lime and "Mixed Alkalies"	51·5	53·1	54·0
	Mean	52·2	52·2	55·9
	SERIES 3.—With Nitrogen per acre, equal to al			
7	275 lbs. Nitrate of Soda, alone	*	51·3	58·1
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	50·7	52·4	53·(
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	50·9	52·6	54·(
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	50·5	52·5	54·(
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	51·4	53·1	54·(
	Mean	50·9	52·4	53·(
	SERIES 4.—With Nitrogen per acre, equal to ab			
12	550 lbs. Nitrate of Soda, alone	*	49·7	53·(
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	49·1	51·3	52·(
14	2000 lbs. Rape Cake, alone	51·7	51·3	52·(
15	300 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	50·6	51·3	53·(
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	49·5	51·7	52·(
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	50·6	51·4	52·(
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	51·2	51·5	53·(
19	2000 lbs. Rape Cake, and Superphosphate of Lime	51·3	51·6	53·(
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	51·4	50·4	53·(
	Mean	50·7	51·1	53·(

* No Nitrate of Soda in 1853; but Sulphate of Potass, and Superphosphate of Lime.

ix consecutive Years on the same Land—1852, 53, 54, 55, 56, an
ted, Herts.)

SED CORN—in Lbs. and Tenths.

857.	Average Annual.	Difference according to Manure.	With what Standard compared.
eries.			
52·1	51·7		
52·3	52·1		
52·2	51·9		
54·1	52·0	0·1	More than Unmanured.
anures, only.			
52·5	52·0	0·1	More than Unmanured.
52·7	51·8	0·1	Less than Unmanured.
52·7	51·9	..	Same as Unmanured.
52·0	51·9	..	Same as Unmanured.
both without and with direct Mineral Manures.			
52·9	† 51·9	..	Same as Unmanured.
51·9	51·5	0·4	Less than Unmanured.
52·1	51·8	0·5	Less than 'Mixed Alkalies' (No. 4).
54·3	51·5	0·3	Less than Superphosphate of Lime (No. 5).
54·7	52·0	0·1	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
53·2	51·7	0·2	Less than Mean of Mineral Series.
both without and with direct Mineral Manures.			
52·0	† 50·9	1·0	Less than Unmanured.
52·0	50·7	1·2	Less than Unmanured.
52·2	50·9	1·0	Less than Unmanured.
52·0	50·7	1·3	Less than "Mixed Alkalies" (No 4).
52·5	50·6	1·2	Less than Superphosphate of Lime (No. 5).
52·6	50·4	1·5	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6).
54·1	51·1	0·9	Less than "Mixed Alkalies" (No. 4).
52·8	51·2	0·6	Less than Superphosphate of Lime (No. 5).
54·1	50·7	1.2	Less than Superphosphate of Lime, and "Mixed Alkalies" (No. 6)
52·3	50·8	1·1	Less than Mean of Mineral Series.

† Taken for 5 years only.

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES :— (Hoos.

TABLE VIII.—MEAN RESULTS of each CHARACTERISTIC MANURE, or Cl.

Classes.	General Description of Manuring.	1853.
	Dressed Corn p	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	26 2
2	Farmyard Manure (14 tons per Acre, per Annum)	33 0
3	Mean by Mineral Manures, only	29 0
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	38 0
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)	40 1
	Mean	33 1
	T	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	1336
2	Farmyard Manure (14 tons per Acre per Annum)	1644
3	Mean by Mineral Manures, only	1461
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	2100
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An.) (both without & with Minerals)	2278
	Mean	1869
	Total S	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	1781
2	Farmyard Manure (14 tons per Acre, per Annum)	2076
3	Mean by Mineral Manures, only	1958
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	2809
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)	2850
	Mean	2206
	Total Produce (	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	3257
2	Farmyard Manure (14 tons per Acre per Annum)	3980
3	Mean by Mineral Manures, only	3634
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	4909
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)	5128
	Mean	4146
	Proportion of T	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	40·9
2	Farmyard Manure (14 tons per Acre, per Annum)	41·0
3	Mean by Mineral Manures, only	43·9
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	42·8
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)	44·1
	Mean	42·6
	Proportion of Dr	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	91·3
2	Farmyard Manure (14 tons per Acre, per Annum)	94·5
3	Mean, by Mineral Manures, only	93·5
4	Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)	89·5
5	Mean, with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)	89·6
	Mean	91·2
	Weight per Bushel	
1	Unmanured (Mean of Unmanured, and Clay and Weed Ashes)	32·6
2	Farmyard Manure (14 tons per Acre, per Annum)	32·7
3	*Mean, by Mineral Manures, only*	32·3
4	*Mean, with Nitrogen= 50 lbs. Ammonia, per Acre per An. (both without & with Minerals)*	32·6
5	*Mean with Nitrogen=100 lbs. Ammonia, per Acre per An. (both without & with Minerals)*	32·7
	Mean	32·5

six consecutive Years on the same Land—1852, 53, 54, 55, 56, and 1857.
nsted. Herts.)

RES, for each of the separate Years; that is, comparing Season with Season.

EACH YEAR.			Total	Average	Average Annual Increase by Manure.	
1855.	1856.	1857.	(6 Years).	Annual.		With what Standard compared.
els and Pecks.						
34 2½ 30 0½	15 0½ 32 0½	30 1½ 51 1½	167 3½ 259 1	28 0 43 0½	15 0½	Over Unmanured.
36 0½ 47 0½ 49 2½	18 0½ 28 2½ 34 2½	35 0 48 2½ 59 3½	190 1½ 258 2½ 282 3½	31 2½ 42 2 47 0½	8 2½ 10 3½ 15 1½	Over Unmanured. Over Mean of Mineral Series. Over Mean of Mineral Series.
43 2½	25 3	45 0	230 3	38 2		
—Lbs.						
1934 2705	886 1656	1679 2915	9,512 14,443	1585 2407	822	Over Unmanured.
1996 2324 2996	947 1550 1464	1981 2699 3339	10,679 14,226 15,816	1768 2394 2643	178 631 880	Over Unmanured. Over Mean of Mineral Series. Over Mean of Mineral Series.
2309	1379	2511	12,936	2159		
er Acre—Lbs.						
1934 3047	1082 2210	1804 3649	10,561 16,789	1760 2790	1030	Over Unmanured.
1994 3115 4027	1020 2181 3217	1788 2952 3500	11,809 17,538 21,344	1885 2925 3570	125 1040 1685	Over Unmanured. Over Mean of Mineral Series. Over Mean of Mineral Series.
2939	1982	2488	15,496	2586		
ogether) per Acre—Lbs.						
3868 5862	1916 3866	3286 5504	20,078 31,182	3345 5197	1852	Over Unmanured.
3970 5709 6713	1967 3781 5071	3714 5341 6840	21,887 31,864 37,162	3648 5319 6218	303 1670 2565	Over Unmanured. Over Mean of Mineral Series. Over Mean of Mineral Series.
4223	3311	4948	28,488	4744		
Total Produce.						
50·0 47·2	46·2 42·8	51·2 47·8	.. ..	47·4 45·5	1·9	Less than Unmanured.
50·0 45·5 40·1	48·1 41·6 36·6	51·9 50·3 48·8	.. .. ..	48·3 44·9 42·4	0·9 3·4 5·9	More than Unmanured. Less than Mean of Mineral Series. Less than Mean of Mineral Series.
46·6	43·1	50·0	..	45·7		
Total Corn.						
94·6 96·1	85·0 91·5	94·3 95·4	.. ..	91·2 98·7	2·5	More than Unmanured.
96·0 94·0 92·6	90·3 88·5 88·2	96·1 98·4 95·5	.. .. ..	96·7 91·7 91·1	2·5 2·0 2·6	More than Unmanured. Less than Mean of Mineral Series. Less than Mean of Mineral Series.
94·7	88·7	96·5	..	92·8		
Lbs. and Tenths						
52·5 46·9	49·8 47·1	52·2 54·1	.. ..	51·9 52·0	0·1	More than Unmanured.
52·6 51·9 49·1	47·8 49·9 46·8	53·0 56·3 53·3	.. .. ..	51·9 51·7 50·8	0·2 1·1	Same as Unmanured. Less than Mean of Mineral Series. Less than Mean of Mineral Series.
51·9	47·9	53·2	..	51·7		

RESULTS of EXPERIMENTS on the GROWTH of BARLEY by different MANURES:— (Hoos-F

TABLE IX.—MEAN ANNUAL RESULTS of each of the diffe

Experiments	MANURES. (Quantities per Acre, per Annum).	PARTICULARS OF QU	
		Proportion of Total Corn, in 100 Total Produce.	Proportion of Dressed Corn, in 100 Total Corn
		SERIES. 1—Ge	
1	No Manure	46·6	90·5
2	20 bushels Clay and Weed Ashes	48·2	92·0
	Mean	47·4	91·2
3	14 tons Farmyard Manure	45·5	93·7
		SERIES 2.	
4	Mixed Alkalies (Sulphates of Potash, Soda, and Magnesia)	47·5	92·4
5	Superphosphate of Lime	48·6	94·7
6	Superphosphate of Lime and "Mixed Alkalies"	48·8	94·1
	Mean	48·3	93·7
	SERIES 3.—With Nitrogen per acre, equal to abo		
7	275 lbs. Nitrate of Soda, alone	45·2	91·8
8	100 lbs. each, Sulphate and Muriate of Ammonia, alone	46·8	90·8
9	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	45·0	90·6
10	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	44·1	92·5
11	100 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	44·0	92·9
	Mean	44·9	91·7
	SERIES 4.—With Nitrogen per acre, equal to a		
12	550 lbs. Nitrate of Soda, alone	42·9	91·3
13	200 lbs. each, Sulphate and Muriate of Ammonia, alone	45·0	89·6
14	2000 lbs. Rape Cake, alone	42·7	92·4
15	200 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	42·2	89·1
16	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime	41·7	90·7
17	200 lbs. each, Sulphate and Muriate of Ammonia, and Superphosphate of Lime, and "Mixed Alkalies"	40·6	91·7
18	2000 lbs. Rape Cake, and "Mixed Alkalies"	42·3	92·
19	2000 lbs. Rape Cake, and Superphosphate of Lime	42·3	91·
20	2000 lbs. Rape Cake, and Superphosphate of Lime, and "Mixed Alkalies"	42·0	91
	Mean	42·4	91·

nsecutive Years on the same Land—1852, 53, 54, 55, 56, and 1857. Herts.)

king for each the average of six Years.

PARTICULARS OF QUANTITY.										
al Produce re).		Average Annual Increase, where Mineral Manures are employed, compared with equal other conditions, without them.			Average Annual Increase, where Nitrogen is added in Manure, compared with equal other conditions, without it.			Average Annual Total Increase by Manure over the Standard Unmanured.		
Straw.	Total Produce.	Corn.	Straw.	Total Produce.	Corn.	Straw.	Total Produce.	Corn.	Straw.	Total Produce.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1612	3391									
1708	3800									
1760	3845									
2790	5197							822	1060	1852
, only.										
1796	3423	42	36	78				42	36	78
1846	3594	103	86	249				103	86	249
2012	3926	329	252	581				329	252	581
1885	3648	178	125	303				178	125	303
without and with direct Mineral Manures.										
2962	5296				779	1102	1881	799	1102	1881
2538	4729				606	778	1384	606	778	1384
2784	5056	81	246	327	645	988	1638	687	1024	1711
3174	5719	354	636	990	797	1329	2125	900	1414	2314
3267	5853	405	729	1134	682	1255	1937	1011	1507	2518
2925	5319	240	537	817	710	1090	1792	809	1165	1974
without and with direct Mineral Manures.										
3652	6198				1081	1772	2853	1081	1772	2853
3101	5704				1018	1431	2449	1018	1431	2449
3548	6212				1079	1788	2867	1079	1788	2867
3312	5758	—102	121	—41	814	1516	2330	856	1552	2408
3915	6590	172	624	796	1027	1969	2996	1190	2055	3245
4073	6874	198	692	1080	867	2081	2948	1216	2213	3529
3390	5805	—159	—158	—317	878	1594	2472	920	1630	2550
3682	6806	9	84	93	925	1786	2711	1088	1872	2960
3688	6800	—2	90	88	748	1926	2674	1077	1877	2955
3670	6213	9	274	283	940	1727	2667	1058	1810	2868

It not unfrequently happens, too, that some passing abnormal conditions, may affect the crop more strikingly than from the registry of characters for a period would be traceable—unless with the aid of coincident careful observation, and consideration of the stage of progress and tendencies of growth at the time, of the crop itself.

Still some broad features of climatic influence may usefully be indicated in connection with the very different amounts and character of produce obtained under equal supplied conditions in the several seasons. To make these more intelligible, it will be well to bring to one view from the Tables, some few statements of quantity and quality of produce, illustrative of the effects on the crop of the different seasons. This is done in the short Summary Table, No. X., which follows. Perhaps upon the whole, the produce obtained year after year by a pretty complete purely mineral manure, is open to as little exception, taken as a measure or representative of the intrinsic influence of season upon the crop, as that under any other individual condition of manuring which our series includes. Accordingly the results of the Mixed Mineral Manure, No. VI., are selected for this purpose; and in the Summary Table (No. X.), is given each of our enumerated characters of quantity and quality of the produce by the manure in question, in each of the six years of the experiments.

TABLE X.

SHOWING the QUALITY and QUANTITY of the produce of BARLEY, by a full purely MINERAL MANURE, in each of the six Seasons.

Years.	Particulars of Quality.			Particulars of Quantity.			
				Produce per Acre.			
	Proportion of Total Corn in 100 Total Produce.	Proportion of Dressed Corn in 100 Total Corn.	Weight per Bushel of Dressed Corn.	Dressed Corn.	Total Corn.	Straw and Chaff.	Total Produce.
			lbs.	bush. pcks.	lbs.	lbs.	lbs.
1852	45·4	92·5	51·5	32 3	1819	2189	4008
1853	46·8	92·1	52·1	35 2½	2017	2295	4312
1854	47·8	95·6	54·0	42 0	2374	2595	4969
1855	50·6	95·4	53·1	37 0¾	2067	2015	4082
1856	49·1	91·3	47·0	19 3	1018	1057	2075
1857	53·3	97·6	53·7	39 3¼	2191	1920	4111
Average .	48·8	94·1	51·9	34 2	1914	2012	3926

The examination of this Table will show the actual and comparative influence of the respective seasons, upon the seven different characters of the produce recorded. It is seen at a glance, that no one season carries with it high condition on every

character of quality and quantity. A clearer perception of how ever-varying are the mutual adaptations of climatic character to stage and tendency of development of the plant, will however be gained by looking at the results in a somewhat converse form. Thus, in Table XI., for each particular of quality and quantity of produce, the years themselves are arranged, in the order in which they severally afford the highest result.

TABLE XI.

ORDER of the SEASONS in influencing the several characters of the QUALITY and QUANTITY of the PRODUCE of BARLEY, grown year after year, by purely Mineral Manures.

	Order of adaptation of the years	1st.	2nd.	3rd.	4th.	5th.	6th.
For Quality as represented by	Proportion of Total Corn in 100 Total Produce	1857	1855	1856	1854	1853	1852
	Proportion of Dressed Corn in 100 Total Corn.	1857	1854	1855	1852	1853	1856
	Weight per Bushel of Dressed Corn (lbs.) .	1854	1857	1855	1853	1852	1856
	Summary of Order for Quality of Produce . .	1857	1854	1855	1853	1852	1856
For Quantity as represented by	Total Corn per Acre (lbs.)	1854	1857	1855	1853	1852	1856
	Total Straw per Acre (lbs.)	1854	1853	1852	1855	1857	1856
	Total Produce (Corn and Straw) per Acre (lbs.)	1854	1853	1857	1855	1852	1856
	Summary of Order for Quantity of Produce . .	1854	1857	1855	1853	1852	1856
	Summary of Order for both Quality and Quantity of Produce	1854	1857	1855	1853	1852	1856

From these two Tables we gather (and the indication is upon the whole borne out by the produce of the other manures), that although 1854 was the year of considerably the highest *actual amount* of corn as well as straw—that is, the year of highest *quantity*—it gave by no means a relatively high *proportion* of corn. In respect to the latter point, of the other seasons, 1857 and 1855 stood considerably higher than 1854. It is at once seen on the other hand that, of all the years, 1856 was strikingly the worst in every point, both of quantity and quality, excepting the one of *proportion* of total corn; and it may be mentioned, that even in this it was so, where nitrogenous manures were employed.

Setting our standard of qualities of season for tendency to *corn*, rather than for the production of bulk of total produce—with which, under high farming, there would seldom be the highest either actual amount of corn, or proportion of it to the manure employed—it may be said that high character involves generally, during the later periods of growth, high relative temperature, with this a high range, a limited amount and distribution of rain, and high relative degree of barometric pressure. So far as general coincidence on these more prominent points is concerned, both

1857 and 1855, the years (particularly the former) of high proportion of corn, stand higher in the meteorological registry than 1854, which was the year of largest total produce, both corn and straw, and of highest weight per bushel of corn. The characters of season favouring quality and quantity respectively, are indeed in a certain degree opposite; and the high actual amount of corn in 1854, was due rather to enormous general growth, succeeded by pretty favourable maturing conditions.

The characters of the season of 1854 were indeed, almost throughout, much more those of continuity and bulk of growth than of special tendency to seeding. Thus, the seed was put in rather earlier than in any of the other years—April was comparatively warm, with little though distributed rain, and a moist atmosphere—May had scarcely average temperatures, a moist atmosphere, a very large fall of rain, and a large number of rainy days—June averaged very low maximum temperatures, and had a very small range of temperature, a moderately moist atmosphere, and not much amount, but considerable distribution of rain—July averaged rather low temperatures, had only a moderate amount and distribution of rain, and not much moisture in the atmosphere. Lastly, August commenced with low temperatures, had then for a period only moderate and even low temperatures, but concluded with higher ones; it had a large amount of rain in the earlier, a small amount in the intermediate, and still less in the later periods, also almost throughout, a moderately dry atmosphere—thus giving conditions of further growth almost up to the last, and finally, favourable maturing characters. Taking the season of 1854 as a whole then, we have a long and almost unbroken period favouring extended growth, and finally, good conditions of ripening. The result is an enormous bulk of total produce, and though the largest *actual*, nearly the smallest *proportional* amount of corn.

Let us take another extreme. Tables X. and XI. show that 1856 was the worst of all the years, for almost every point, both of quality and quantity of produce. Its vicissitudes were very great. April was moderately warm and wet—May had comparatively very little warm weather, its amount and distribution of rain were very large, but the atmosphere was frequently comparatively dry—June reached both high and very low temperatures, had a considerable mean range of temperature, not much amount, and limited distribution of rain, but frequently a very moist atmosphere—July again reached comparatively very low temperatures, had a more than average range, considerably below the average fall of rain, yet a moderate average amount of moisture of atmosphere. Finally, August, the ripening month, in its first week reached both very high and very low temperatures, giving an enormous range, and had very little rain; in its second week,

ugust had again very high maximum temperatures, but some-
hat high minimum also, giving a high mean, and still a com-
ratively high range, and its fall of rain, though small, was
istributed; in the third week the mean maximum temperatures
ere unusually low, and the minimum moderately so, giving low
oth mean and range, there was more or less rain every day, and
very large total fall; and lastly, the fourth week again averaged
ery low maximum temperatures, but not low minimum, and had
at a small fall of rain, whilst almost throughout the month there
as a good deal of atmospheric moisture. Thus then, with some
ery high maximum, and some very low minimum temperatures
uring the first half of the month (which was the last fortnight of
rowth of the standing crop), little rain, but frequently a moist
tmosphere—then followed at the time of cutting with very low
emperatures, a very excessive fall of rain, and still a moist
tmosphere—we had a laid and sprouted crop. This season of
856 was then one of very great vicissitudes, almost throughout
he important stages of the progress of the plant. Hence, as
Tables X. and XI. show, and as presently will be further seen,
e had the worst crop of any in the series, in every point, both
f quality and quantity of the produce.

These few statements of the characters of the seasons most
ntrasted in their effects upon the crop, will at any rate serve
direct the mind of the reader upon the subject, and thus pre-
e the way for a consideration of what are the actual amounts
variation in the quantity and quality of the produce—with
al conditions supplied at the cost of the farmer—due to that
ontrollable influence, *the weather*.

Discussing then the actual amounts of variation in the quality
quantity of the produce dependent upon variation of *season*,
re going to that more peculiarly due to *manuring*, the Sum-
y Table, No. VIII., will afford the facts for our illustration.
have in that Table the mean produce for each of the years,
each of five characteristic conditions of manuring, so that,
ugh not just now considering for themselves the effects of the
erent manures, we shall nevertheless see to what extent the
pective seasons, compared one with another, maintain any
aracteristic influence upon the crop under widely differing con-
ions of manuring.

Looking first to the mean unmanured produce, it is at once
erved that we have in some of the seasons twice as much,
h of corn and of straw, as in others. Thus, the total un-
nured produce (corn and straw together) is, in the very bad
son of 1856, only 1918 lbs.; whereas in 1854 and in 1855 it is
re than twice, and in the other three years nearly twice as
ch. The amount of dressed corn, without manure, in 1856,

was only 15 bushels, and the weight per bushel was under 50 lbs. In 1857 we had, without manure, 30¼ bushels, with a weight of 52¼ lbs. per bushel: in 1854, 34¼ bushels, with 53½ lbs. weight per bushel; in 1855 nearly 35 bushels, of 52½ lbs. weight each, and in 1852 and 1853 from 26 to 27 bushels, with 52½ and 51 lbs. weight per bushel respectively. Again, in 1857 and 1855, the seasons favourable to corn-yielding, we had 50 to 51 per cent. of corn in total produce; and in the other years there was only from 15 to 47 per cent. The proportion of corn was the least in 1854, the year of heaviest produce, and in 1856 the one of lightest produce, and also of greatest inferiority in every other respect. The proportion of corn dressed out as offal was also more than twice as great in 1856, and in the comparatively inferior season 1853, as in either of the favourable seasons 1857, 1855, or 1854.

A further inspection of Table VIII. will show, that the same general relation of the seasons to one another as regards the relative quantity and quality of the produce they yielded is traceable under the very various conditions of manuring, as with the unmanured crop. It is true that with heavy manuring, the worse proportionally, is the effect of adverse season. But the general result still remains, that the seasons keep their position in relation to one another almost unchanged, whatever the condition of manuring, even though the actual amount of produce with manure, as is frequently the case, is nearly double that without it. In every year (though in 1857 less than in the rest) the crops most heavily manured were much laid, and more or less damaged, and hence the much best *proportion of corn in total produce* with these manures, even in the last year 1857, than where the crop was unmanured, or only mineral manures were employed.

From the pervading influence of *season*, by which the produce may be double as much one year as another, even with one and the same set of conditions supplied by the farmer, and by which when unfavourable, the crops most highly manured suffer most it results that the amount of produce obtained for a given outlay in manure may be only half as much in some seasons as in others. And, as will be more fully illustrated further on, the higher the condition of manuring, if beyond a somewhat even narrow limit, the less will be the return of produce for a given quantity of manure. This brings us to a consideration of the effects of the individual *manures* employed in the experiment, leaving the reader to study for himself more in detail the variations in result from season to season, which have been above broadly indicated.

Dispensing then with any further detailed consideration of the

ds for the individual years, which are provided for full ence in Tables I. to VIII. inclusive, we will now direct more cular attention to Table IX., in which is given the mean al result over six consecutive years, of each of the twenty iptions of manure employed.

fore entering upon the examination of the *mean annual result* ie individual manures, it should be stated that, in the detailed es there is no evidence of any gradual either falling off, or ase of result from year to year, such as should vitiate the tion of the average of the six years, as a measure of the al or comparative effects of the different manures. Thus, first two years were in many points very much alike in result, they agree very nearly with the average of the six. The two years, 1854 and 1855, but particularly the former, were e the average in their amount of produce. Lastly, the fifth 1856, was the worst of all; and the present year, 1857, the in succession, was above the average on every point, and ly the best of the series on some. So far then the average t of the six years may be taken, provided only that the ber and character of the *seasons themselves* are admitted to d a sufficient range, to indicate a fair average effect of the rent manures. How far results obtained by the use of the description of manure to the same crop grown on the same through a series of years consecutively, can afford an indi- on of the requirements of barley as grown ordinarily in rota- , is of course a matter of separate consideration.

he descriptions of the manures, and the quantities of them loyed, are partially given in the Tables, and the necessary her explanations on these points will be found at p. 3 In Tables the twenty plots are divided into four classes, according ie general character of their manures, as under:—

t *Gauge Series.*—Comprising the unmanured portions, and a on manured with clay and weed ashes; also the farmyard ure plot. The mean result of the unmanured and ash por- taken together, forms one—and that of the farmyard manure ier—standard of comparison, by which to judge of the effects e other manures.

d *Series.—Mineral Manures* only—Comprising three plots; having "*Mixed Alkalies*" (sulphates of potash, soda, and esia); another Superphosphate of Lime; and the third, both "Mixed Alkalies," and Superphosphate of Lime. The s of this series should show us the extreme effect obtainable the available normal supplies of nitrogen (terrestrial and spheric). They also serve as a point of comparison of the s of nitrogen artificially supplied in addition, as in the wing Series 3 and 4.

3rd *Series*.—In this series nitrogen is supplied by manure at a rate equal to about 50 lbs. of ammonia per acre per annum. The nitrogen is supplied respectively in the forms of nitrate of soda, and of an equal mixture of sulphate and muriate of ammonia. The ammonical salts are supplied both alone, and in admixture with each of the three several mineral-manure conditions of Series 2. The amount of nitrogen here supplied is perhaps fully as much as can be used with impunity for the barley crop on the soil in question, taking the average of seasons. The crop would be over-luxuriant and laid, with a larger amount.

4th *Series*.—Here the nitrogen is supplied at a rate equal to about 100 lbs. of ammonia per acre per annum. This amount is given in the three separate forms of nitrate of soda, the equal mixture of sulphate and muriate of ammonia, and as rape cake.* The mixture of ammonical salts, and also the rape cake, are each used, both alone and in admixture with each of the three mineral conditions above specified. As above implied, the nitrogen here provided, is beyond that which gives the best result in proportion to the amount of manure employed.

According to the notes taken in the field, the unmanured, and the only mineral manured portions, as a rule stood up till the time of cutting. The crops with nitrogen equal 50 lbs. ammonia per acre, were generally more or less laid; as also were those grown by farmyard manure. Those having nitrogen equal 100 lbs. or more of ammonia per acre were invariably laid; and in every year, excepting in 1857, very much and injuriously so, the crops being far too heavy to bear any moderate amount of rain about or after the time of heading.

The effect of the "Mixed Alkalies" on the condition of the crop, whether used alone or in admixture with nitrogenous manures, was invariably somewhat to retard its ripening. Superphosphate of lime, on the contrary, whether alone or in admixture, always tending to early ripening. The effect was most striking. So much so indeed, that latterly it has been thought desirable to cut the crops at different times as they came ripe; the superphosphate ones and the farmyard-manure coming to the scythe more than a week earlier than the others. It will presently be seen that the superphosphate had a marked effect on the quantity of produce also, and especially on the tendency to corn. Owing to the frequent falling of the crop, where nitrogenous manures were also employed, the result was, how-

* For convenience, the rape cake plots are classed as in the Tables; but it is probable that the 2000 lbs. per acre employed, would contain nearer 100 lbs. of *nitrogen*; the latter amount would be equal to about 121¼ instead of 100 lbs. of *ammonia*.

eldom so favourable at harvest as from appearances it ısly promised to be.

ing in mind these general tendencies of effect of the ıt manures, which, owing to the incidental though uncon- e fluctuations of season, are of course not so exactly cally reflected as they would be under constant and ıble conditions of climate, let us see what really are the ative results which the figures show.

the left hand division of Table IX. will be found the e annual effects of the different manures upon the *quality* produce. These are indicated by the *proportion of corn total produce, the proportion of dressed corn in total corn, e weight per bushel of the dressed corn.* In the right hand n of the Table are given the particulars of *quantity;* , the average annual bushels of corn per acre, and the t in lbs. per acre, respectively of the total corn, of the and of total produce (corn and straw together).

re are also given under the head of particulars of *quantity,* erage annual *increase* of corn and of straw, &c., by different es, compared with the produce of others adopted as rds.

king first to the columns of *quality,* it is seen that the n of the ashes, which do not increase the total produce, a tendency to an increased proportion of corn, a somewhat proportion of dressed corn, and a slightly higher average per bushel of dressed corn, when compared with the unma- produce. Taking the same standard of comparison, the ard manure, probably because the crop was generally laid, t give a higher average proportion of total corn; but the pro- ı of dressed corn, and the weight per bushel of the dressed were somewhat higher. Comparing Series with Series, the l manures alone gave higher qualities of produce in all respects than either the unmanured produce, or that of the with nitrogenous manures. The produce of the Series with en=50 lbs. of ammonia per acre, was generally inferior in ualities enumerated to the unmanured produce; and that of ries with the nitrogen equal to 100 lbs. or more of ammonia re, stands lower still in all these points of quality, depen- ı they do so materially on the standing up and favourable ing of the crop.

ng a little more into detail, it is seen that where the ıl manures were used alone, the superphosphate of lime marked effect on the proportion of total corn; and also upon erfection of the corn; as indicated by the amount of the d, in 100 of the total corn. The influence of the mineral es on the quality of the produce, and especially that of the

superphosphate of lime, was exactly the reverse when used in combination with the nitrogenous manures. This result was however, obviously due to the over luxuriance and laying of the crop, rather than to the intrinsic effects of the mineral manures themselves; which, when the produce was not too heavy for the season, were seen to be of a directly opposite character. In fact the gradations of inferiority as to tendency to corn, and quality of produce generally, are shown by the figures to be so closely connected with increase in total quantity, that they must obviously be attributed much more to the adverse influence of season upon a bulky crop than to any intrinsic influence of the manures employed.

Before leaving the question of the qualities of the produce under the different manures, it may be observed, that whether yielding nitrogen equal to 50 or 100 lbs. of ammonia per acre, the ammonical salts gave a higher average proportion of corn in the total produce than the nitrate of soda. This would appear to be due to a more rapid action of the nitrate. For, as will presently be seen, though it gave a less *proportion* of corn, it gave in both cases a larger *actual amount* of it, and particularly a larger amount of straw, or total bulk of produce, indicating a more luxuriant growth.

Let us now turn from the columns of *quality* to those of *quantity*. We see, as already alluded to, that the clay and weed ashes gave a slightly higher average amount of corn, and lower average amount of straw, and of total produce, than the unmanured plot. The latter indeed gave an annual average of 91 lbs. more *total produce* than the clay and weed ashes. There need therefore be no fear entertained that the results of the other manures, which, for the purpose of even distribution over the land were mixed with always smaller quantities of these ashes, are at all materially affected thereby,

As before stated, it is the mean result of the unmanured plots and of that manured with the clay and weed ashes, that is taken as the standard wherewith to compare the effects of the different manures. The average annual amount of this standard or normal produce of the unaided soil and season, was 1585 lbs. (=25 bushels) of corn, 1760 lbs. of straw, &c.; making 3345 lbs. of total produce, corn and straw together. Above this amount, 14 tons per acre of ordinary farmyard dung, gave an average annual increase of 822 lbs. (=about 15 bushels) of corn, and 1030 lbs. of straw. The yearly gain in total produce by this manuring was therefore 1852 lbs., or considerably less than a ton.

Reckoning the farmyard manure to contain about 75 per cent. of water, and the 1852 lbs. of increased produce obtained by it to consist of about one-sixth water, we have an average annual

d of 1543 lbs. of gross dry substance in the increase of pro-
, by the use of about 7840 lbs. of gross dry substance in
ure. It is clear, therefore, that the great bulk of the solid
ter of the dung, which consists mainly of highly carbonaceous
nic substance, had little to do with the increase in the pro-
of the barley.

study of the effects of the other individual manures, which
ce one or more, as the case may be, of the constituents of
dung, should enable us to judge to which constituent, or
tituents, of the latter, its effects on the barley-crop are
ly due.

y the annual use of "*mixed alkalies*"—sulphates of potash,
, and magnesia—in amounts containing much more of the
ctive bases than the total annual produce, we obtain an ave-
annual increase of only 42 lbs. of corn and 36 lbs of straw,
3 lbs. total increase.

he annual application of the *superphosphate of lime alone* gave
arly increase of 163 lbs. of corn, and 86 lbs. of straw, =
lbs. of total increase; or 171 lbs. more than the "*mixed
ies.*"

he combination of both the "*mixed alkalies*" and the *super-
phate of lime* gave an annual increase of 329 lbs. of corn and
lbs. of straw, = 581 lbs. of total increase; that is 503 lbs.
total increase than the "*mixed alkalies*" alone; 332 lbs. more
the *superphosphate of lime* alone; and 254 lbs. more than
sum of the increase by the two manures when each was used
rately.

e shall refer more specially to the beneficial action of direct
eral manures on the barley-crop further on; but that we may
o with advantage, it will be convenient first to consider the
lts of Series 3 and 4, in which they were employed, not
e as in the cases just considered, but in conjunction with
genous manures.

nstead of 3345 lbs. of total produce, the average annual amount
out manure, we have by the use of *nitrate of soda alone*
taining nitrogen equal to about 50 lbs. of ammonia), 5226 lbs.,
by *salts of ammonia alone* (supplying about the same acreage
unt of nitrogen) we have an average annual total produce of
9 lbs. The average annual increase by nitrate of soda was
er more than 14 bushels of dressed corn (779 lbs. total corn),
1102 lbs. of straw; and that by the ammoniacal salts was about
bushels of dressed corn (= 606 lbs. total corn), and 778 lbs. of
w. There was, indeed, by *nitrate of soda alone*, only 43 lbs.
corn, and even more straw and total gross produce, than by
14 tons of farmyard-manure. *The salts of ammonia alone*, which

yielded a less result than the nitrate in relation to the assumed amount of nitrogen supplied, gave 216 lbs. less corn, and about 252 lbs. less straw, than the farmyard manure.

Unless, then, we are to attribute some important influence to the soda of the nitrate, or to the sulphuric acid and chlorine of the ammoniacal salts, we have here, by the supply in manure, of available nitrogen alone (= about 50 lbs. ammonia per acre per annum), in one case even more, and in the other somewhat less, of annual total produce, than by the whole of the constituents of the annually supplied 14 tons of dung.

In experiments 9, 10, and 11, we have the same amount of ammoniacal salts as in No. 8, but now in conjunction with one or other of the respective mineral manures of Nos. 4, 5, and 6. The addition of the "mixed alkalies" (salts of potash, soda, and magnesia) to the ammoniacal salts, raises the average annual produce by 81 lbs. of corn and 246 lbs. of straw. Estimating the result the converse way, the addition of the ammoniacal salts, as in No. 9, to the "*mixed alkalies*," as in No. 4, has given an increase of 645 lbs. corn and 988 lbs. of straw. Or, if we compare the result of the combination of the ammoniacal salts and the "mixed alkalies" with the unmanured produce, the combination has given an increase of 687 lbs. of corn and 1024 lbs. of straw, against 822 lbs. increase of corn and 1030 lbs. of straw by the farmyard-manure. Supplied nitrogen (about 41 lbs. per acre), and salts of the fixed alkaline bases, have therefore nearly reached the result of 14 tons of farmyard-manure.

In experiment No. 10 *superphosphate of lime* is the mineral manure added to the ammoniacal salts of No. 8. The addition of the *superphosphate of lime* increased the produce by 354 lbs. of corn and 636 lbs. of straw (= 990 lbs. total produce) over that by the ammoniacal salts alone. Calculating conversely, the addition of *ammoniacal salts to superphosphate of lime* gave an average annual increase of 797 lbs. of corn and 1328 lbs. of straw over the produce of the latter alone, against an increase of 606 lbs. of corn, and 778 lbs. of straw, over the unmanured produce when the same amount of ammoniacal salts were used alone. Again, by the conjoint action of ammoniacal salts and superphosphate of lime, we get an average annual increase over the unmanured produce, of 960 lbs. of corn and 1414 lbs. of straw, against an increase of only 822 lbs. of corn and 1030 lbs. of straw, by the farmyard-manure.

In experiment No. 11 we have, in addition to the same amount of ammoniacal salts as before (containing about 50 lbs. of ammonia), both the "*mixed alkalies*" and the *superphosphate of lime*, as in No. 6. The increase of No. 11 over No. 10 by the addi-

of the "*mixed alkalies*" to the superphosphate of lime and oniacal salts of the latter, is only 51 lbs. of corn and 93 lbs. raw; or little more than that of the "mixed alkalies" over unmanured produce when they were used alone. Thus the annual gain (in experiment 11) by the addition of both the ed alkalies" and phosphatic manure to the ammoniacal salts xperiment 8), is 405 lbs. of corn and 729 lbs. straw; that is, more than by the addition to the ammoniacal salts of phosphate of lime alone. On the other hand, calculating ffect of the addition of the 50 lbs. of ammonia per acre per n to the mixed mineral manure of No. 6, it is seen to be bs. of corn and 1255 lbs. of straw. And lastly, the average al increase over the unmanured produce, due to the conjoint s of the ammoniacal salts, the "mixed alkalies," and the phosphate of lime, is 1011 lbs. of corn and 1507 lbs. of straw; is 189 lbs. corn and 477 lbs. straw, more than by the farm-manure.

m the results of Series 3, as a whole, we see that the mean al increase by the supply to the soil of *nitrogen* = 50 lbs. of nia per acre per annum, in the five different states, or con-s of combination, is 710 lbs. of corn and 1090 lbs. of straw, 2 lbs. less corn, and 60 lbs. more straw, than by the farm-manure. Or, taking the increase over the unmanured pro-due to the conjoint action of the mineral manures and ied nitrogen (as in experiments 9, 10, and 11), its mean al amount, calculating from 18 experiments (that is with three ent mineral conditions each over six years), is 64 lbs. more and 285 lbs. more straw than by the dung. Or, lastly, if ke the conjoint action of the 50 lbs. of ammonia, and those al manures only which contain phosphates, we have from 100 0 lbs. more corn and from 400 to 500 lbs. more straw, per acre nnum, by such a combination, than by farmyard-manure.

the next series (4), as already mentioned, there was about as much nitrogen supplied per acre as in experiments 7, 8, 0, and 11, in which, as has just been seen, the amount of ice averaged more, and sometimes greatly exceeded, that by ge annual supply of farmyard dung. It should be stated in utset, that the quantities of nitrogen now under considera-were considerably beyond what the barley could turn to good nt with such seasons on the soil in question, as was shown e invariable falling of the crop, and the consequent deficient rtion and quality of the corn. The result of this was, that ad in every case very much less increase of produce for a amount of manure in Series 4 than in Series 3. In fact, is, on the average, only about once and a half as much

increase, obtained by the use of nitrogen equal 100 lbs. or more of ammonia per acre per annum, as by the 50 lbs. or its equivalent of nitrogen. Bearing in mind this general result of an excessive amount of nitrogen supplied, the figures are still deserving some examination.

In this Series, 4, the nitrogen was provided in the three separate forms of *nitrate of soda*, an equal mixture of *sulphate and muriate of ammonia*, and *rape-cake*. In Series 3, the quantities of ammoniacal salts and nitrate of soda employed per acre were 100 lbs. each, sulphate and muriate of ammonia, and 275 lbs. of the nitrate; the 200 lbs. of mixed ammoniacal salts and the 275 lbs. of nitrate of soda having been taken as containing respectively in round numbers 41 lbs. of nitrogen, = 50 lbs. of ammonia.

In Series, 4, double the amounts, maintaining therefore the same proportions to one another, of the ammoniacal salts and nitrate were employed. These quantities were adopted on the assumption that the equal mixture of the ammoniacal salts, in the condition in which they are sold in commerce for manure (though we always use the best at our command for experimental purposes), will average about 8 per cent. of water and impurity, and the nitrate about $8\frac{1}{4}$ per cent.* It is probable, however, that the nitrate will frequently come up nearer to the chemical standard of composition than the ammoniacal salts, and if so, our supposed equivalent amount of nitrate will contain a correspondingly larger amount of nitrogen than the ammoniacal salts: and this may partly, though not entirely, account for the greater effects obtained by the nitrate employed. The amount of rape-cake employed in Series 4 was 2000 lbs. per acre per annum; and it is assumed in the Tables, and also sometimes when speaking of the results, that the amount of nitrogen thus supplied was about the same as that in the larger amounts of ammoniacal salts and nitrate used by its side. This would, however, suppose a lower per cent. of nitrogen in the rape-cake than the average of our own determinations, or the records of those of others, would indicate. It is, indeed, not improbable that the 2000 lbs. of rape-cake would frequently contain nitrogen equal to from 110 to even 120 lbs. ammonia. It is probable, on the other hand, that the nitrogen of the rape-cake will be given up from its existing combinations, in less proportion each year than that in either of the other two forms. Although, therefore, all the experiments included in Series 4 are so brought together for the convenience of

* These deductions are probably in both cases rather excessive. It frequently happens, in fact, that sulphate of ammonia in the bulk, will average less water of crystalization than is theoretically accorded to it.

ssification, and are thus assumed to represent about equal nual supplies of nitrogen to the crop, this assumption must ly be taken with the qualifications above stated.

In addition to the *nitrogen* we have of course in the nitrate *soda*, in the ammoniacal salts sulphuric acid and chlorine, and the rape-cake not only a considerable amount of carbon-yield-g organic matter, but also a considerable amount of the mineral atters of the seeds from which the cake is made. The rape-ke, at least, must therefore be considered as providing, not only ailable *nitrogen*, probably in larger quantity than the other mbinations, but *mineral matters* also. And it will, besides ese, yield a constant supply of carbonic acid, or other carbon oducts of transformation of its organic substance.

Besides the nitrate, the salts of ammonia, and the rape-cake, h used alone, the mixture of the ammoniacal salts, and also rape-cake, were each used in conjunction with the respective eral manures before described—namely the "*mixed alkalies*," *superphosphate of lime*, and the mixture of the two.

Here, where the nitrate of soda was used in the larger quantity, also where it was used in smaller amount (Experiment 7), it wed a mixture of sulphate of potash and superphosphate of applied in the first year of the experiments (1852), but not e. What portion of the indicated superiority of the nitrate the ammoniacal salts, whether used in the larger or the ler quantity, may be due to this fact, unfortunately cannot be rmined. On this point it may be noticed, that it was only the later years of the experiments that the ammoniacal salts short of the nitrate in result. It was, therefore, only after an ual exhaustion of the annually available minerals of the soil, aking off a series of corn crops highly manured with available ogen, that the nitrate, following after supplied minerals, showed superiority. Where the larger quantities were used, the age annual excess both of corn and straw by the nitrate over ammoniacal salts was, however, considerably less than where smaller amounts were employed. Again, as the nitrate in the er quantity, gave almost identically the same average annual unts both of corn and of straw as the rape-cake with its equal larger amounts of nitrogen and abundant minerals, and as the ivalent amount of ammoniacal salts approaches nearer in result the nitrate, and to the rape-cake with its minerals, than did the moniacal salts to the nitrate when used in smaller quantity—h of course, then, requiring much less minerals from the soil ve must judge, that part of the indicated superiority of the ate is really due to greater rapidity of its action; by which, h the underground and aboveground feeders of the plant were

constantly open to a larger area for the collection of nutriment, at each period of progression, than in the case of the ammoniacal salts.

A mere glance at the comparable experiments in the Series 3 and 4, shows how very small, especially in corn, was the increase obtained by the addition of a second 50 lbs. of ammonia, or its equivalent of nitrogen. In fact, its effect is in every instance much less than, and on the average only about half as great as, that of the first 50 lbs. This point we shall presently further illustrate by the aid of analysis. But the general fact should be clearly borne in mind in drawing comparisons among the individual experiments.

Going to actual figures, it is not a little remarkable that, as before alluded to, approximately equal amounts of nitrogen, indiscriminately in nitrate of soda, in ammoniacal salts, and in rape-cake, should over a period of five or six years, give us an average annual yield of corn so nearly identical. Thus the nitrate gave an average annual increase of 1081 lbs., the ammoniacal salts 1018 lbs., and the rape-cake 1079 lbs. of corn. The nitrate and the rape-cake thus gave an average difference of only 2 lbs. per acre per annum of corn; the ammoniacal salts yielding about 60 lbs. less than either. In straw, the nitrate and rape-cake gave respectively an annual increase of 1772 and 1788 lbs., or the latter (the rape-cake) only 16 lbs. more than the former: the ammoniacal salts gave, however, about 340 to 350 lbs. less straw annually than the nitrate or the rape-cake. It is also worthy of remark, that, whilst the nitrate of soda and the rape-cake, when used alone, gave respectively 1081 and 1079 lbs. annual average increase of corn, the rape-cake with the superphosphate, as in Experiment 19, and with superphosphate and mixed alkalies, as in 20, gave almost identically the same amounts, namely, 1088 and 1077 lbs. Again, of straw, the nitrate and rape-cake alone, gave respectively 1772 and 1788 lbs. of annual increase, whilst the plots 19 and 20, with the same amount of rape-cake and the minerals, do not give 100 lbs. more—the amount being for the rape-cake and superphosphate 1872 lbs., and for the rape-cake, superphosphates, and mixed alkalies 1878 lbs. As there is no other point so nearly in common with these four different combinations as their amounts of nitrogen, there can be little doubt that their main or most characteristic effect upon the barley crop, was due to the available nitrogen they respectively supplied.

In calling attention to this very close coincidence in the result from a given amount of nitrogen supplied in different forms, it should at the same time be remarked, that the fact of the supply being in all these cases too heavy to allow of their full action and

the favourable ripening of the crop, should lead us to take the figures as only indicating a general equivalency, other things being equal, of nitrogen provided in these different forms. It has, indeed, already been shown to be probable, that the nitrate of soda, especially when not used in excess, may yield its quantum of produce more rapidly than ammoniacal salts; but evidence is yet wanting to enable us to decide, whether or not a given amount of nitrate supplied to the soil will really *eventually* yield a larger produce in proportion to its nitrogen. Further in reference to the above observed coincidence of result, it may be remarked that the amounts, though so far from the proportional increase obtained when nitrogen was used in smaller quantity, being still so nearly identical, affords some illustration of the absolute limit which *season* puts to the advantages of very high manuring. The facts next to be noticed will, indeed, show how contingent is the uniformity of action upon the influence of season on the progress and maturing of the crop.

In Experiment No. 15, as compared with No. 13, we see the influence of the addition of the "*Mixed Alkalies*" to the double amount of ammoniacal salts; and in No. 18, compared with No. 14, we see the effect of the "Mixed Alkalies" when added to rape-cake, containing an equal or larger amount of nitrogen. In both cases the average annual produce of corn, and consequently the increase, was less by about 160 lbs. than when the respective nitrogenous manures were used without these "Mixed Alkalies," the characteristic effect of which has been shown to be, rather to retard the ripening of the crop. The average produce of straw was, indeed, 121 lbs. more by the addition of the "Mixed Alkalies" to the ammoniacal salts; but as the deficiency of corn was more than this, the result is, that the average total produce is 41 lbs. less than by the ammoniacal salts alone. Again, the produce of straw, as well as that of corn, by the combination of the "Mixed Alkalies" and *rape-cake*, is considerably less than by the rape-cake alone—the deficiency being 159 lbs. corn, 158 lbs. straw = 317 lbs. total produce per acre per annum.

The superphosphate of lime, which, when added to the smaller amount of ammoniacal salts, gave an average annual increase over the produce of the ammoniacal salts alone of 354 lbs. corn, 636 lbs. straw = 990 lbs. total increase, gives, when added to the larger amount of these salts, only 172 lbs. more corn and 624 lbs. more straw; equal only 796 instead of 990 lbs. more total increase. The addition of the superphosphate of lime to the rape-cake, which latter already contained a liberal supply of other mineral constituents required by the growing barley, is very far less efficient still. By this combination we get only 9 lbs. more of corn and

84 lbs. more of straw, = 93 lbs. more of average total produce than by the rape-cake alone.

The addition of both superphosphate of lime and "*Mixed Alkalies*" to the small amount of ammoniacal salts, increased the result by 105 lbs. of corn, 729 lbs. straw, = 1134 lbs. total increase; but their addition to the larger amount of ammoniacal salts only increased the produce by 198 lbs. corn, 882 lbs. straw = 1080 lbs. total increase. The addition of the same full mineral manure to the rape-cake did very much less. Thus the combination gave 2 lbs. less corn and only 90 lbs. more straw than the rape-cake alone.

From all that has been said as to the very much increased luxuriance of growth where the double amounts of nitrogen were applied by manure, it will be sufficiently clear, that these apparently less results of both given amounts of nitrogen and of mineral manures, when the former—the nitrogen—was employed in so large an amount, was due in reality, not to the inaction of the manures, but to the over-luxuriance they induced in the earlier stages of growth, and the consequent falling of the crop and loss of final result. It is obvious, therefore, that the numerical results of Series 4, do not at all fairly represent the intrinsic productive values of the different combinations.

That over-luxuriance, and not the contrary, was the cause of the failure, is evident from the fact, that although the rape-cake used alone gave more increase than the ammoniacal salts alone, when they were respectively used with superphosphate of lime and superphosphate of lime and the "Mixed Alkalies" together (which increased the produce with smaller supplies of nitrogen than the rape-cake, which when alone was the most active, gave less results than the ammoniacal salts.

The general conclusions from a review of the results of Series 4 are, that with an excessive amount of nitrogenous manure, the immediate return of crop from a given amount of the expensive manurial constituent—*available nitrogen*—will be much diminished; that the proportion of straw will be greater—an expensive end to which to devote such costly means; and lastly, that the addition under these circumstances of a liberal supply of certain otherwise effective mineral manures, may be quite inadequate to counteract the injurious effect; their tendency being then as seasons go, still more to increase the straw in greater proportion than the corn.

From a review of the whole of the results relating to the action of special manures upon the barley-crop—taking the average of six successive years of growth by each, on land in an agricultural sense somewhat exhausted—we learn—

at exclusively mineral manures, and especially those con-
ng phosphoric acid, annually increased the produce of barley;
doing so in the first year of their application on land in the
ition described.

at with barley grown continuously on the same land (as was
case with wheat), nitrogenous manures had a much more
ing effect than mineral manures.

at by the annual supply of nitrogenous manures alone (nitrate
da or ammoniacal salts), larger successive crops both of corn
straw were obtained, than by the annual use of 14 tons of
yard-manure—with all its minerals, and certainly more nitro-
than either the nitrate or ammoniacal salts employed by its

at within certain limits, even on this comparatively exhausted
(and it would probably be more nearly so on soils in ordinary
ition for the crop), nitrate of soda, ammoniacal salts, and
-cake, all increase the produce of barley, approximately in
ortion to the amounts of nitrogen they respectively supplied.
r comparative effects will, however, vary somewhat according
ason, the nitrate being generally more rapid in its action.

at to obtain a maximum amount of increase in proportion
he nitrogen given in manure, the barley-crop will, on the
ge of seasons, bear a considerably less acreage amount of it
is required by the wheat crop under similar circumstances.

at the effect of a given amount of nitrogen, if not excessive,
be considerably increased by the addition of certain mineral
ures, especially those containing phosphates. The action of
mineral manures is very much increased under such circum-
es; that is, their application gives very much more increase,
there is present a liberal supply of *available nitrogen within
oil*, than when there is not.

other words, a soil brought by previous cropping into a
ition to require manure of some kind before it will grow a
crop of corn, when afterwards cropped year after year with
y, only yields full crops when a liberal amount of nitrogen
pplied to the soil. Mineral manures, especially phosphates,
derably increase the action of the nitrogen so supplied; but
ffect of such mineral manures on the increase of crop, will be
mely limited, without there be a liberal amount of *available
gen within the soil itself.*

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e conclusions enumerated above have been arrived at by the
deration of experiments on the growth of barley by various
ituents of manure, applied year after year on the same land.
ill be interesting, with the information thus gained, to inquire

into the amounts of barley obtained in some of the same seasons, under very different, but also to a certain extent known conditions of growth, in other fields. By the comparisons that will thus be afforded, we shall get some useful check upon the conclusions hitherto arrived at. At the same time, so far as those conclusions are to be trusted upon their own independent evidence, they will in their turn, serve to afford some insight into the comparative chemical conditions of soil, for exhaustion or otherwise, to which the results yet to be recorded are in all probability due. In this review we shall have perhaps still clearer evidence than has been already adduced, of how utterly unavailing is a liberal provision of the necessary mineral constituents in the soil to give even a moderate crop of barley, unless there be *at the same time, within the soil, available nitrogen.*

The first set of collateral experiments to be noticed is one in which barley was taken successively from the same land, in the seasons 1853, 1854, and 1855 respectively, after ten successive crops of turnips, which had been grown experimentally with different manures.

Accordingly, in Table XII. we have the produce of barley as under :—

1st. On a plot where turnips had been grown for ten years, and in the last seven without any manure whatever ; the unmanured produce, leaves and roots together, averaging little more than two tons per acre per annum.

2nd. On a plot, comprising several, which respectively had liberal supplies of different mineral manures only, every year during the last eight of the growth of the turnips. The produce of the turnips was here much greater than on the unmanured plot. On some portion of this and the following plots all, and on other portions only some, of the mineral constituents of the turnip-crop were supplied each year in much larger quantity than they were taken off in the crops. The produce of the succeeding barley was, however, on all so very nearly alike, that only the mean produce over all, is here given.

3rd. On a plot which had had the same various mineral manures on different portions, as above, for the turnips ; and in addition during six years—1845 to 1850 inclusive—an average annual amount of about 44 lbs. of nitrogen per acre in the form of ammoniacal salts ; after which the minerals only were applied for the two remaining years of roots.

4th. On a plot which had had the same set of mineral manures as Nos. 2 and 3 up to the end of the turnip experiments, and average annual addition during the six intermediate years—1845 to 1850 inclusive—of about 95 lbs. of nitrogen in the form

pe-cake which, of course, further contained mineral matters
id carbonaceous organic substance also.

5th. On a plot with the same mineral manures for the turnips
in Nos. 2, 3, and 4, and in addition during the six interme-
ate years—1845 to 1850 inclusive—an average aunual supply
about 139 lbs. of nitrogen, given as a mixture of both rape-cake
id ammoniacal salts.

It is not to our present purpose to discuss the relative amounts
turnips grown on these five different plots. But it may be
ated generally, that the mineral manures alone, of No. 2, gave
ry much larger crops than the unmanured plot No. 1; and that
e addition of the nitrogenous and other organic constituents
the mineral manures, as on Nos. 3, 4, and 5, always gave a
rther increment of increase. It should be added, however, that
e produce by the six years' addition of nitrogenous manures did
t, even in the eight years—that is, including the two which
ceeded the application—return in either of the three cases the
trogen in increase which had been supplied as manure. Where
trogen was supplied in the manure for the turnips, we should
erefore expect—unless it were evaporated or drained in some
rm from the soil, distributed too widely throughout it, fixed in
in an unavailable condition of combination, or in some way
issipated during the growth of the plant—that there would be
me remaining available for the three succeeding crops of barley.
ndeed the object of growing the barley three years in succession
ver these plots without any fresh manure, was to reduce them as
ar as possible to an equal condition as to available nitrogen,
efore commencing a new series of turnip experiments.

Before giving the Table of the produce of barley obtained in
e three years—1853, 1854, and 1855—as above described, it
ould be further explained, that in the second year of barley (1854)
portion of the land, numbered 6 in the Table, which had the
neral manures only for the turnips, received in the second year
barley about 82 lbs. of nitrogen per acre in the form of ammo-
cal salts; the barley following again in 1855, but without any
ther addition of nitrogen. Lastly, another portion with the
neral manures alone previously (No. 7 in the Table), received
the same year (1854), for the barley, about 82 lbs. of nitrogen
the form of nitrate of soda; and in the third year (1855) about
lbs. more nitrogen in the same form.

The produce of barley obtained after ten years' turnips on these
en plots is given in Table XII., which follows:—

TABLE XII.—EXPERIMENTS with BARLEY, GROWN after TURNIPS ten Years in for several Years (Barn-Field

No.	DESCRIPTION OF MANURES FOR THE TURNIPS.	
		Total Corn per
1	Unmanured since 1845	
2	Mineral Manures only, since 1844	
3	Mineral Manures, since 1844, and Ammoniacal Salts	1845-50 inclusive (in all 268 lbs. Nitrogen)
4	Mineral Manures, since 1844, and Rape Cake	1845-50 inclusive (in all = 568 lbs. Nitrogen)
5	Mineral Manures, since 1844, and Rape Cake, and Ammoniacal Salts	1845-50 inclusive (in all = 681 lbs. Nitrogen)
6	Part of Mineral Plot, with 400 lbs. Ammoniacal Salts = 82 lbs. Nitrogen per Acre, in 1854	
7	Part of Mineral Plot, with 550 lbs. Nitrate of Soda = 82 lbs. Nitrogen per Acre, in 1854, and with 112 lbs. Nitrate of Soda = 17 lbs. Nitrogen per Acre, in 1855	
		Total Straw per
1	Unmanured since 1845	
2	Mineral Manures only, since 1844	
3	Mineral Manures, since 1844, and Ammoniacal Salts	1845-50 inclusive (in all 268 lbs. Nitrogen)
4	Mineral Manures, since 1844, and Rape Cake	1845-50 inclusive (in all = 568 lbs. Nitrogen)
5	Mineral Manures, since 1844, and Rape Cake and Ammoniacal Salts	1845-50 inclusive (in all = 681 lbs. Nitrogen)
6	Part of Mineral Plot. with 400 lbs. Ammoniacal Salts = 82 lbs. Nitrogen per Acre, in 1854	
7	Part of Mineral Plot, with 550 lbs. Nitrate of Soda = 82 lbs. Nitrogen per Acre, in 1854, and with 112 lbs. Nitrate of Soda = 17 lbs. Nitrogen per Acre, in 1855	
		Total Produce (Corn and
1	Unmanured since 1845	
2	Mineral Manures only, since 1844	
3	Mineral Manures, since 1844, and Ammoniacal Salts	1845-50 inclusive (in all 268 lbs. Nitrogen)
4	Mineral Manures, since 1844, and Rape Cake	1845-50 inclusive (in all = 568 lbs. Nitrogen)
5	Mineral Manures, since 1844, and Rape Cake and Ammoniacal Salts	1845-50 inclusive (in all = 681 lbs. Nitrogen)
6	Part of Mineral Plot, with 400 lbs. Ammoniacal Salts = 82 lbs. Nitrogen per Acre, in 1854	
7	Part of Mineral Plot, with 550 lbs. Nitrate of Soda = 82 lbs. Nitrogen per Acre, in 1854, and with 112 lbs. Nitrate of Soda = 17 lbs. Nitrogen per Acre, in 1855	
		Dressed Corn per Acre-
1	Unmanured since 1845	
2	Mineral Manures only, since 1844	
3	Mineral Manures, since 1844, and Ammoniacal Salts	1845-50 inclusive (in all 268 lbs. Nitrogen)
4	Mineral Manures, since 1844, and Rape Cake	1845-50 inclusive (in all = 568 lbs. Nitrogen)
5	Mineral Manures, since 1844, and Rape Cake and Ammoniacal Salts	1845-50 inclusive (in all = 681 lbs. Nitrogen)
6	Part of Mineral Plot, with 400 lbs. Ammoniacal Salts = 82 lbs. Nitrogen per Acre, in 1854	
7	Part of Mineral Plot, with 550 lbs. Nitrate of Soda = 82 lbs. Nitrogen per Acre, in 1854, and with 112 lbs. Nitrate of Soda = 17 lbs. Nitrogen per Acre, in 1855	
		Weight per Bushel of Dressed
1	Unmanured since 1845	
2	Mineral Manures only, since 1844	
3	Mineral Manures, since 1844, and Ammoniacal Salts	1845-50 inclusive (in all 268 lbs. Nitrogen)
4	Mineral Manures, since 1844, and Rape Cake	1845-50 inclusive (in all = 568 lbs. Nitrogen)
5	Mineral Manures, since 1844, and Rape Cake and Ammoniacal Salts	1845-50 inclusive (in all = 681 lbs. Nitrogen)
6	Part of Mineral Plot, with 400 lbs. Ammoniacal Salts = 82 lbs. Nitrogen per Acre, in 1854	
7	Part of Mineral Plot, with 550 lbs. Nitrate of Soda = 82 lbs. Nitrogen per Acre, in 1854, and with 112 lbs. Nitrate of Soda = 17 lbs. Nitrogen per Acre, in 1855	

* In these cases the Total and Average Annual *Produce* are given for two years only; and the

ession, which were manured with the same kind of Manure on the same PLOT ecutively.

ıamsted, Herts)

	PRODUCE PER ACRE.				INCREASE PER ACRE, BY MANURE.		
S.	1854.	1855.	TOTAL.	Average Annual.	TOTAL.	Average Annual.	
in lbs.							
9	1012	1016	3177	1059			
5	1077	1078	3240	1113	168	84	Over Unmanured.
4	1167	1154	3645	1215	805	102	Over Mineral Manures.
8	1366	1306	4339	1446	980	338	Over Mineral Manures.
5	1336	1262	4295	1432	945	315	Over Mineral Manures.
.	2998	1424	* 4422	* 2211	* 2367	* 1183	Over Mineral Manures (2 years).
.	3234	2268	* 5495	* 2746	* 3337	* 1668	Over Mineral Manures (2 years).
in lbs.							
8	1330	1156	4194	1398			
5	1307	1128	3868	1819	236	79	Less than Unmanured.
9	1524	1177	4241	1414	283	94	Over Mineral Manures.
0	1748	1409	5102	1701	1144	381	Over Mineral Manures.
1	1708	1278	4952	1651	994	331	Over Mineral Manures.
.	4379	1498	* 5807	* 2903	* 3262	* 1641	Over Mineral Manures (2 years).
.	4781	2459	* 7240	* 3620	* 4715	* 2357	Over Mineral Manures (2 years).
per Acre—in lbs.							
7	2542	2172	7371	2457			
8	2474	2306	7398	2462	73	25	Less than Unmanured.
4	2691	2681	7886	2629	589	196	Over Mineral Manures.
8	3171	2712	9441	3147	2143	714	Over Mineral Manures.
6	3186	2566	9387	3079	1989	646	Over Mineral Manures.
.	7377	2952	* 10,229	* 5114	* 5549	* 2774	Over Mineral Manures (2 years).
.	8006	4727	* 12,782	* 6386	* 8052	* 4026	Over Mineral Manures (2 years).
hels and Pecks.							
0½	17 3½	19 0	56 3½	18 3½			
1½	19 2	19 3½	58 3½	19 3½	3 0	1 0	Over Unmanured.
0½	21 0½	21 2½	65 3½	22 0	6 0½	2 0	Over Mineral Manures.
2½	24 2½	23 3½	77 0½	25 3	17 1½	5 3	Over Mineral Manures.
0½	26 3½	26 3	76 2½	25 2½	16 3½	5 2½	Over Mineral Manures.
	53 1½	26 2½	* 78 3½	* 39 1½	* 39 1½	* 19 2½	Over Mineral Manures (2 years).
	54 3½	40 1½	* 95 0½	* 47 2½	* 55 3	* 27 3½	Over Mineral Manures (2 years).
in lbs. and tenths.							
9	53·25	51·00	..	52·12			
0	53·40	51·07	..	52·23			
7	53·46	51·60	..	52·53			
8	53·95	51·89	..	52·92			
2	53·94	51·88	..	52·78			
.	54·29	52·19	..	53·24			
.	53·51	53·04	..	53·27			

and Average Annual *Increase* also, are calculated only for the two corresponding years.

Taking together the results relating to the continuous growth of barley on Hoos-field, given in former tables, and those here given in Table XII., we have the means of comparing the produce of barley grown without manure during three years in succession, after a series of unmanured turnip crops, with that obtained in the same seasons without manure, on land of very similar character; but which, differed widely in the condition induced by the very different cropping, &c., to which it had been submitted. Next, confining attention to the results of the barley after ten years' turnips (in Table XII.), we have, taking the produce after the *unmanured* turnips as the standard of comparison, the means of judging of the effects on the succeeding barley, of an enormous excess of mineral manures annually applied for the previous turnip crops. Compared with the produce of barley obtained after this large residue of mineral manures—by this time, no doubt, considerably distributed through the soil—we can trace the increase due to any available residue of nitrogen, where it was added in the different forms to the mineral manures for the turnips. Lastly, by the effects of the direct addition of nitrogenous manures for the barley (as in Nos. 6 and 7), to the residual high mineral condition, we can judge, whether or not, any deficiency of the crop on the other plots was probably attributable to a want of *available nitrogen within the soil*.

If the characteristic influence of a *rotation of crops*, upon the increased growth of the cereals, be at all materially due to the elaboration in the soil, during the growth of other crops, of the necessary mineral supplies for the white crop, it might surely be expected that here, after ten meagre, unmanured crops of turnips, appropriating no amount of silicates, we should have, if ever it were possible, a large produce of barley, depending, with these rich stores of prepared mineral food in the soil, upon atmospheric sources for its nitrogen? If not after the many crops of *unmanured* turnips, surely after those provided with a very large excess of other mineral matters than silicates—the crop taking none of the latter out—we should have enough elaborated and conserved in the soil both of these and of all other mineral constituents, to yield the fullest crop of barley which it is possible to obtain by the conjoint influence of a very rich mineral condition of soil, and the normal season supplies of available nitrogen? What is the result?

In the following Table (XIII.), is afforded a summary view of the produce of barley without manure for the three years in question, in Hoos-field, devoted to the experiments on the continuous growth of barley by different manures, side by side with that

ned after many successive turnip crops, which had been ctively grown without manure, and with an excessive y of mineral manures :—

TABLE XIII.

of UNMANURED BARLEY, in the continuous SERIES in HOOS-FIELD, ed with that after many Crops of Turnips either Unmanured or with l Manures.

	Produce of Barley per Acre.					Increase, or Loss, per Acre.	
	1853.	1854.	1855.	Total (3 Years.)	Average Annual.	Total (3 Years).	Average Annual.
Dressed Corn per Acre, in Bushels and Pecks.							
	bsh. pk.	bsh. pk.	bsh. pk.	bsh. pk.	bsh. pk.	bsh. pk.	bsh. pk.
Unmanured Plots	26 3	34 1	34 3¼	95 3¼	31 3¾		
After Unmanured Turnips	20 0¼	17 3¼	19 0	56 3¼	18 3¾		
After Mineral-manured Turnips	20 1¾	19 2	19 3¾	59 3¾	19 3¾	3 0	1 0
Total Corn, per Acre, lbs.							
Unmanured Plots	1547	1940	1934	5421	1807		
After Unmanured Turnips	1149	1012	1016	3177	1059		
After Mineral-manured Turnips	1185	1077	1078	3340	1113	163	54
Total Straw, per Acre, lbs.							
Unmanured Plots	1865	2395	1934	6194	2065		
After Unmanured Turnips	1508	1530	1156	4194	1398		
After Mineral-manured Turnips	1433	1897	1198	3958	1319	—236	—79
Total Produce (Corn and Straw) per Acre, lbs.							
Unmanured Plots	3412	4335	3868	11615	3872		
After Unmanured Turnips	2657	2542	2172	7371	2457		
After Mineral-manured Turnips	2618	2474	2206	7298	2432	—73	—25

omparing the produce of barley on the unmanured plots in two fields, and without going into the detail of the separate s, it is seen that, although in the field of continuous barley riments, there was an annual average produce over the three s, of 31 bushels 3¾ pecks of dressed corn, or 1807 lbs. total , there were, after the ten meagre crops of turnips, only bushels 3¾ pecks of dressed, and 1059 lbs. of total corn. Of r, the average annual yield for the three years was 2065 lbs. he field of continuous barley, and only 1398 lbs. after the ips. We have then, less than two-thirds as much corn, and about two-thirds as much straw, after the ten years' turnips, the field whence much more corn had been recently taken. act, a produce of scarcely 19 bushels per acre per annum of

barley corn, and little more than half a ton of straw—toge
equal to not a ton of dry substance of produce—must
admitted to be exceedingly small. The *condition* of the
after ten successive crops of turnips, must have been for l
growth, at the lowest possible point.

That a liberal supply of mineral constituents distri
through the soil, cannot restore this exhausted fertility, is se
the produce of barley after the mineral-manured turnips.
ten years of turnips, the last eight of which were grown by
sive supplies of mineral manures, we have an annual aver
54 lbs., or 1 bushel of corn more, and 79 lbs. of straw
= 25 lbs. *less total produce*, than after the unmanured turnip

In what constituent or constituents had these unmanured
mineral-manured turnips exhausted the soil, in so far as the
production of barley was concerned, to a point even far
that arrived at in the other field by the previous growth
crop of wheat, one crop of barley with sulphate of ammonia
one crop unmanured—that is, three white straw crops in s
sion without mineral manure? An examination of Table
will throw some light on this point.

It has already been said, that there was an average a
increase of 54 lbs. of corn, but a decrease of 25 lbs total pr
where the barley succeeded the mineral-manured turnips,
pared with the produce after the unmanured turnips. T
now the produce after the *mineral-manured* turnips a
standard of comparison, there was, where in the six middle
of the ten of turnips ammoniacal salts had also been applie
annual average increase in the succeeding barley of 102 lbs.
and 94 lbs. straw, = 196 lbs. total produce.

Still comparing with the produce after the mineral-ma
turnips, we have, where in six years out of the ten rape-cak
employed in addition to the minerals, an average annual in
of succeeding barley, of 333 lbs. corn, and 381 lbs. straw, = 71
total produce.

Lastly, where during six years both ammoniacal salts and
cake were added to the mineral manures for the turnips, the
ceeding barley gave an annual average increase of 315 lbs.
and 331 lbs. straw, = 646 lbs. total produce.

We had then, with a residue in the soil of merely m
manures, even a loss of produce of barley—due to a greater gr
and consequent greater exhaustion of other matters, by
turnip. We find, on the other hand, a perceptable gain i
barley wherever the turnips had received either ammoniacal
or rape-cake as well as the mineral manures. Even here,
ever, the produce, with this nitrogenous and full mineral re

e soil, was not equal to the annual unmanured produce in
her field, where the barley was growing continuously.
at the beneficial effect of the residue of the rape-cake was
ne to the mineral constituents it supplied, may be judged by
act, that the residue of the direct mineral manures had not
ich effect. It was undoubtedly a residue of *available nitrogen*
the soil, that gave the increase of produce of barley where
mmoniacal salts or rape-cake had been employed for the
s. If this be admitted, we have in the facts, at once a
ful illustration of the degree of reliance upon nitrogen in
il of the turnip crop, and of the utter incapability of rich
es of mineral constituents in the soil, to be of any avail in
g agricultural quantities of barley, unless there be at the
time *within the soil*, a liberal amount of *available nitrogen*.
further proof be wanted that the necessary mineral consti-
were in abundance, and available in this turnip-exhausted
or very full crops of barley, provided only available nitrogen
also within the reach of the roots of the plants, it is to be
in the results of the experiments Nos. 6 and 7 (Table XII).
ammoniacal salts and nitrate of soda respectively, were
to a part of the turnip plot, where the residue of the
p mineral manures alone, had been unavailing to increase
roduce of barley.
1853 the produce of barley on the mineral-manured turnip-
was 20½ bushels. In 1854 those portions of the mineral-
ured plots left without further manure gave 19½ bushels. But
e now (in 1854), about 82 lbs. of nitrogen per acre were added
mmoniacal salts, we had, instead of 19½ bushels, 52½ bushels
arley; and where the same quantity of nitrogen was added
itrate of soda, 54¾ bushels. The increase in the produce of
was in greater proportion still. By the addition of the
oniacal salts, the straw was raised from 1397 lbs. per acre
1379 lbs.; and by the nitrate of soda it was increased to
lbs. The total produce (corn and straw together), was
from 3 to 3½ times as great by the simple addition of am-
iacal salts or nitrate of soda. And it may be observed, in
ing, that here again nitrate of soda was more active than an
med equal amount of nitrogen given as ammoniacal salts.
is very remarkable too, that although the produce after the
eral-manured turnips was little more than half as much as
unmanured produce in the field of continuous barley experi-
ts, yet the addition of a given amount of nitrogen gave very
ly identical results in both fields. Thus, after the mineral-
ured turnips, we had, with the ammoniacal salts and nitrate
soda respectively, 7377 lbs. and 8005 lbs. of total produce
n and straw together); and in the field of continuous barley

experiments we had, with the same amount of nitrogen, given as ammoniacal salts (without minerals), 7548 lbs., and as nitrate of soda (second year without minerals), 7400 lbs. of total produce. Again, in the same field of continuous barley experiments, the mean result of direct mineral manures and ammoniacal salts together, was 8320 lbs.; and that of even more nitrogen given as rape-cake (itself supplying also mineral constituents, as well as carbonaceous organic matter), with, in 3 out of 4 cases, direct mineral manures also, was 8150 lbs.

In the contrasts and coincidences afforded by the results in these two fields, we have the clearest evidence, that it was in *available nitrogen* for the barley crop, that the previously mineral-manured turnip soil had become deficient, as compared with the unmanured land in the field of continuous barley experiments. It is evident moreover, that on the mineral-manured turnip plots there was an abundant provision of the requisite mineral constituents for an exceedingly full crop, within the reach of the barley plant, provided only *available nitrogen*, were also within the reach of its roots. Lastly, with the widely-differing condition of the land in the two fields without further nitrogenous manure, and the approximation to equal amounts of produce, when, with comparable other conditions, both are supplied with a full dressing of such manure, again we learn, how marked is the influence of season on the productive effects of our most active manures.

With the further light upon the "*condition*" of soil required by the barley crop, which the examination of the produce obtained after ten years of turnips, and its comparison with that of the other field, affords, we will now examine the results obtained in still another field, under circumstances differing widely from those of either of the other two.

The field now to be spoken of, immediately adjoins the one where the barley succeeded ten years of turnips, as last under notice. In 1848 three portions of nearly an acre each were set apart for separate experiments on the chemical statistics of *rotations of crops*.

For all three of these portions of land the rotation chosen was —turnips, barley, clover, wheat. When the second course of clover came round, after a lapse of only four years, it, as was to be expected, failed; and hence, half of each plot was sown with beans, and the other half fallowed instead. None of the crops were to be manured excepting the turnips, which commenced each course.

The plot devoted to *Rotation No.* 1 was to remain entirely unmanured—even for the turnips—course after course.

e turnips of each course, of *Rotation No.* 2, were to be red with superphosphate of lime alone.
e turnips of *Rotation No.* 3 were, each time they came , to be manured with superphosphate of lime, the sulphates tash, soda, and magnesia, 2000 lbs. rape-cake, and 100 lbs. ulphate and muriate of ammonia, per acre.
have here, therefore, three parallel rotations with the same —the one with no manure whatever, course after course; ond with superphosphate of lime alone once in four years; a third with, after the same interval, a mixed manure, sup- liberally to the soil phosphates and other mineral consti- s, and both nitrogen and carbonaceous organic substance.
each of these three four-course rotation experiments has in progress since 1848, they have each afforded us three crops, after turnips respectively so variously manured; ly, in 1849, in 1853, and 1857. And as from half of each p plot, the entire produce, leaves and roots, was carted off, and e other half the roots were eaten by sheep, and the leaves buted over the land, we have the produce of the barley on turnip plot subdivided, so as to show the comparative effects ch, of the drawing off and folding.
thout going into any lengthened detail regarding any other of these rotations than the barley, it may be stated generally, the turnips grown by the full mixed manure, averaged over ns each course, of entire produce, leaves and roots together: the of the last course was, however, rather the smallest of the . The superphosphated turnips gave an average per course 3 to 14 tons leaves and roots, the first crop being some tons , and the last some below that amount. The unmanured ps again, gave an average of 4 to 4½ tons per course, leaves and . But whilst the first unmanured crop amounted to from 10 tons, the second and third did not reach 2 tons each of produce. It need only be further remarked, that as there a much greater falling off in each succeeding turnip crop e it was unmanured, or received only superphosphate of than where there was a full manuring each course, it may dged that the soil contained a larger unexhausted residue of able constituents from previous cropping, &c., at the com- ement of the first course, than at that of the others.
ble XIV., which follows, gives the produce of barley, in each e three courses, of each of these three differently-manured ions. It is also in each case given separately for the portions e the turnips were respectively carted off, or eaten on the

TABLE XIV.—EXPERIMENTS with BARLEY Grown in FOUR-COURSE ROTATIONS, commencing with ROOTS differently MANURED, the same Manures being employed on the same Land for the Roots of the three successive Courses of each Rotation.

(Agdell-Field, Rothamsted, Herts.)

	ROTATION, No. 1. Each Course entirely Unmanured.			ROTATION, No. 2. Each Course commencing with Superphosphate of Lime, alone, for the Root Crop.			ROTATION, No. 3. Each Course commencing with Superphosphate of Lime, Mixed Alkalies, Ammoniacal Salts, and Rape Cake, for the Root Crop.		
	After Turnips Carted off.	After Turnips Fed on Land.	Increase or Loss by folding.	After Turnips Carted off.	After Turnips Fed on Land.	Increase or Loss by folding.	After Turnips Carted off.	After Turnips Fed on Land.	Increase or Loss by folding.
Total Corn per Acre—Lbs.									
Barley of 1st Course—Season, 1849	2681	2734	53	1676	2526	850	1943	2569	626
Barley of 2nd Course—Season, 1853	1947	1930	—17	1875	2341	466	2262	2279	17
Barley of 3rd Course—Season, 1857	2592	2482	—110	1727	2846	1119	2712	3208	496
Mean of the 3 Barley Crops .	2407	2382	—25	1759	2571	812	2306	2819	513
Total Straw per Acre—Lbs.									
Barley of 1st Course—Season, 1849	2992	3182	190	1989	3264	1275	2463	3674	1211
Barley of 2nd Course—Season, 1853	2309	2221	—88	2023	2743	720	2599	3152	553
Barley of 3rd Course—Season, 1857	2465	2430	—35	1545	2687	1142	2417	3487	1070
Mean of the 3 Barley Crops .	2589	2611	22	1852	2898	1046	2493	3438	945
Total Produce (Corn and Straw) per Acre—Lbs.									
Barley of 1st Course—Season, 1849	5673	5916	243	3665	5790	2125	4406	6243	1837
Barley of 2nd Course—Season, 1853	4256	4151	—105	3898	5084	1186	4861	5431	570
Barley of 3rd Course—Season, 1857	5057	4912	—145	3272	5533	2261	5129	7093	1964
Mean of the 3 Barley Crops .	4995	4993	—2	3612	5469	1857	4799	6256	1457
Dressed Corn per Acre, in Bushels and Pecks.									
Barley of 1st Course—Season, 1849	45 0½	46 2	1 1½	28 3	41 3½	13 0½	32 3½	42 3½	10 0
Barley of 2nd Course—Season, 1853	33 1	32 1½	—0 3½	31 3½	38 3½	6 3½	38 0½	35 1	—3 3½
Barley of 3rd Course—Season, 1857	46 0½	44 1	—1 3½	30 3	50 2½	19 3½	47 3½	64 3½	17 0
Mean of the 3 Barley Crops .	41 2	41 0½	—0 1½	30 2	43 3	13 1	39 2½	48 0	8 1
Weight per Bushel of Dressed Corn—Lbs. and Tenths.									
Barley of 1st Course—Season, 1849	56·7	6·8	0·1	56·7	57·6	0·9	57·2	57·1	—0·1
Barley of 2nd Course—Season, 1853	52·3	52·6	0·3	52·9	51·9	—1·0	52·8	51·2	—1·6
Barley of 3rd Course—Season, 1857	54·2	53·7	—0·5	54·1	54·0	—0·1	54·7	54·4	—0·3
Mean of the 3 Barley Crops .	54·4	54·4	0·0	54·6	54·5	—0·1	54·9	54·6	—0·4
Proportion of Total Corn, in 100 Total Produce.									
Barley of 1st Course—Season, 1849	47·3	46·2	—1·1	45·7	43·6	—2·1	44·1	41·1	—3·0
Barley of 2nd Course—Season, 1853	45·7	46·5	0·8	46·5	46·0	—0·5	46·5	42·9	—3·6
Barley of 3rd Course—Season, 1857	51·2	50·5	—0·7	52·8	51·4	—1·4	52·9	50·8	—2·1
Mean of the 3 Barley Crops .	48·1	47·7	—0·4	48·3	47·0	—1·3	47·8	44·6	—3·2
Proportion of Dressed Corn, in 100 Total Corn.									
Barley of 1st Course—Season, 1849	95·5	96·6	1·1	97·4	95·3	—2·1	96·9	96·2	—0·7
Barley of 2nd Course—Season, 1853	89·4	88·1	—1·3	90·1	86·3	—3·8	88·2	81·7	—7·5
Barley of 3rd Course—Season, 1857	96·5	95·8	—0·7	96·3	96·1	—0·2	96·2	97·4	1·2
Mean of the 3 Barley Crops									

The figures in Table XIV. deserve a careful examination by the reader. Our space will only allow us to call special attention to one or two points of prominent interest. To aid us in this, we subjoin in Table XV., given below, a summary statement of the produce of barley obtained where the turnips were carted off in the unmanured rotation, by the side, when at command, of the unmanured produce, in the same years, in the other two fields :—

TABLE XV.

HISTORY OF THE LAND.	Produce of Barley, Unmanured.		
	1849.	1853.	1857
Dressed Corn per Acre, in Bushels and Pecks.			
Agdell-Field—In four-course Rotation after Turnips Unmanured and Carted off	bsh. pk. 45 0½	bsh. pk. 33 1	bsh. pk. 46 0½
Hoos-Field —In continuous Barley Series		26 3	30 1½
Barn-Field —After 10 crops of Turnips Carted off (8 Unmanured)		20 0½	
Total Corn per Acre, lbs.			
Agdell-Field—In four-course Rotation after Turnips Unmanured and Carted off	2681	1947	2592
Hoos-Field —In continuous Barley Series		1547	1679
Barn-Field —After 10 crops of Turnips Carted off (8 Unmanured)		1149	
Total Straw per Acre, lbs.			
Agdell-Field—In four-course Rotation after Turnips Unmanured and Carted off	2992	2309	2465
Hoos-Field —In continuous Barley Series		1865	1604
Barn-Field —After 10 crops of Turnips Carted off (8 Unmanured)		1508	
Total Produce (Corn and Straw) per Acre, lbs.			
Agdell-Field—In four-course Rotation after Turnips Unmanured and Carted off	5673	4256	5057
Hoos-Field —In continuous Barley Series		3412	3283
Barn-Field —After 10 Crops of Turnips Carted off (8 Unmanured)		2657	

The first point of observation brought prominently to light by this summary Table is, that the produce of barley obtained in *rotation*, even when the turnips were both unmanured and carted off, was considerably greater than when the crop was grown annually in succession on the same land. This too was even more strikingly the case in the third unmanured course than previously. It has been already seen that the barley obtained continuously in succession, was, on the other hand, considerably more than that after a series of unmanured turnip crops.

Bearing in mind the point last mentioned, and now referring to Table XIV., it is interesting to observe, that in each of the three seasons of barley in rotation, the produce was considerably less after the carted-off turnips grown by superphosphate of lime, than after those without any manure whatever. After what has already been gathered of the nitrogen-exhausting characters of the

turnip, this result is easily explained by the fact, that much larger crops of turnips were in each course taken from the superphosphated, than from the unmanured rotation land. Consistently with this (omitting the first course when the existing *condition* of the land obviously somewhat interfered with the result in all three rotations), it is on the other hand seen, that the *fed* superphosphated turnips gave larger succeeding crops of barley than the *fed* unmanured ones.

It is worthy of remark, that on the entirely unmanured rotation plot, the barley after the fed-on-turnips was, in the last two courses, when the turnips had amounted to less than 2 tons per acre total produce, even somewhat less than where the corresponding crops of roots had been carted from the land. This was possibly due to more injury being done to the texture of the land by the treading of the sheep, than was compensated by the trifling amount of manure from the consumption of such meagre crops of turnips.

In the case of the full manured turnips, as well as the superphosphated ones, there was, however, always a considerable increase in the succeeding barley by feeding the turnips on the land. As was to be expected, too, the barley after the highly manured turnips, whether carted off or fed on the land, was always heavier than after the corresponding superphosphated ones. On the other hand, the difference in the amount of barley depending on whether the turnips were fed on the land or removed, was considerably greater where the superphosphate of lime alone was employed for the roots. This was partly due, as already implied, to the fact that the removed superphosphated turnips had drawn from the land more of certain constituents not supplied in manure, and therefore left the soil poorer in them for the succeeding barley, than where the full manure, or even no manure whatever (with the consequent meagre turnip crops), was employed. But as there was evidence that, where the highly manured turnips had been fed on the land, it was in too high a condition to yield, as seasons go, so full an amount of produce in proportion to the manure as when the latter was less in quantity, it is obvious that the difference in result by feeding, would be more striking after the superphosphated turnips—where by carting-off the exhaustion was greater, and by folding the manuring was not too high—than where, as on the highly manured plot, both the exhaustion by the removal of the turnips was less, and the manuring by feeding was more excessive. Here again, it may be remarked in passing, the figures teach us how sensitive is the barley crop to the vicissitudes of season, and how liable to injury under them, when manured beyond a certain somewhat narrow limit.

t us now for a moment review as a whole, the various field iments on the growth of barley. It has been found, that the nt of produce when grown after a succession of removed nured, or even highly mineral-manured turnip crops, was elow a moderate agricultural yield. It was seen, that by the e addition of nitrogenous manure to land in this condition, ious crops were raised. When barley was grown without re year after year, on land in a less artificially exhausted con- t than that where ten successive turnip crops had been grown, roduce was considerably greater than after the succession of crops. On this land mineral manures somewhat increased roduce. But, as on the turnip-exhausted land, nitrogenous res did so much more strikingly. In both fields, indeed, mount of available nitrogen supplied to the soil, ruled the nt of produce very much more strikingly, than did the y of the necessary mineral constituents of the crop. In ng barley in *rotation*, on land previously brought to that arative state of exhaustion, in which, under ordinary cul- on with home manuring and ordinary cropping, the conclu- of a course will leave it, the unmanured produce of barley ghout three subsequent courses of an entirely unmanured on, was considerably greater than that where barley was a year after year; and it was still further in excess of that ned after a series of unmanured turnip crops.

re then is a striking effect upon the produce of barley by ng it in a *rotation*—even unmanured—of turnips, barley, r, wheat. When the turnips in such a rotation were u by superphosphate of lime, and by it larger crops of the removed than without manure, the produce of barley was han after the unmanured turnips. Here, too, then, the pro- of barley is diminished after unusual exhaustion by turnip ing. But either the consumption of the superphosphated ps on the land, the residue of a mixed mineral and nitro- s manure after turnips grown by it had been carted off, or onsumption of these turnips on the land, greatly increased subsequent produce of barley above that of the turnip ex- ed rotation land. It could certainly not be the restoration ineral matters, to which, in these cases the increased pro- of barley was mainly due; for the increase was greater by consumption on the land of the merely superphosphated ps, than by the residue of far richer mineral (and organic) re where the turnips grown by it had been removed, taking but a small proportion of the supplied minerals; and it greater still where these highly manured turnips were fed he land, and returned to it a considerable amount of nitrogen, ddition to the already relative excessive amount of minerals.

It was seen too, in the other fields, that mineral manures were quite unavailing to give even moderate crops of barley, unless there were *available nitrogen within the soil.*

It may fairly be concluded, that a characteristic effect of alternating the other crops with the barley, has been to leave more available nitrogen from some source, within the reach of the roots of the latter, than when either this same crop was grown continuously in succession, or when a number of successive turnip crops were previously removed from the land. Barley then, like wheat, requires characteristically what may be termed a nitrogenous *condition* of soil. It cannot, however, under ordinary circumstances, bear such large amounts of nitrogen supplied as wheat; though what it does require, from the habit of the plant, and its usual limited period of growth, should be more confined to the upper layers of soil. For these reasons, barley may often be taken with advantage after a previous white crop, by a spring-dressing merely, of chiefly nitrogenous manure. In such cases the direct addition of mineral manures, especially those containing phosphates, will have a more striking effect than upon the *winter-sown wheat.* The effect of such mineral manures is not only to increase the general growth, but to bring the crop more rapidly to maturity. The more frequent alternative is, that barley is taken after a root-crop, in part, or entirely, fed on the land. The appropriateness of this course for barley rather than for wheat, besides the advantage arising from the season of the year at which the land is generally clear for the corn, rests mainly on the fact, that the manure by folding, with the subsequent light working of the land, is more confined to the superficial layers of soil, in which comparatively, the roots of the barley play more freely.

A disadvantage of growing barley after the folding of sheep on turnips is, that with high farming the land is apt to be thus left in too high a condition for the crop to succeed well in the average of seasons; whilst, on the heavier lands, there is frequently much injury done to the texture, rendering it difficult to get the fine tilth so essential to the favourable growth of barley.

Of direct portable manures for barley, Peruvian guano, or salts of ammonia, or nitrate of soda—either of them with a small quantity of superphosphate of lime—are the best. Rape-cake is also a good manure for barley, but it is generally too high in relative price. These manures, as well as purely mineral manures, are most advantageously applied before, or at the time of sowing, so as to be somewhat distributed through the surface soil by the mechanical operations. As a mere top-dressing nitrate of soda is the best. Of the more exclusively nitrogenous manures—salts of ammonia and nitrate of soda—the nitrate acts somewhat

e rapidly for a given amount of nitrogen supplied. The on of the purely nitrogenous manures, is economised by ad- ture with a small quantity of superphosphate of lime, or other ropriate mineral manure. Other things being equal, the r the barley is sown, the less should be the proportion of ogen in the manure, and the greater that of mineral constitu- ; otherwise the crop is liable to be too luxuriant; and with mited range of root in the soil, it will probably not find mi- al constituents rapidly enough in the later stages of growth, for vourable development and maturing of the seed.

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y the concurrent testimony of field experiments of very ous kinds, we have been led to the conclusion that full crops barley cannot be grown unless there be, by some means, avail- nitrogen provided within the soil. It happens that in tice it is frequently convenient to increase the produce of barley crop by the direct application of portable nitrogenous ures. It is very desirable, therefore, both in a practical scientific point of view, to have some means of judging what is the probable proportion of the nitrogen so supplied in ure, which will, on the average, or under given circum- ces, be recovered in the immediate or successive increase of p obtained. We propose, therefore, to adduce such evidence these points as, by the aid of analysis, we are enabled to vide.

Before passing to this concluding division of the subject, how- r, it may be well to add a few words on the more marked cts of direct mineral manures on the barley than on the wheat p. That such should be found to be the case is seen to be e consistent, on a consideration of the distinctive habits and al circumstances of growth in our rotations, of these two, ertheless much allied crops.

The necessity of considering the various habits and conforma- of the different crops of our rotations in relation to their urces of growth, was prominently insisted upon in our early ers in the Journal of the Royal Agricultural Society ten years . The important bearing of such considerations in modifying conclusions, to which a more purely chemical view of the es and province in a system of manuring of the various con- ents would lead, is one of the first lessons which the progress field experiments teaches. Indeed, in the early years of our experiments, so desirable did it seem, to verify and define more obvious conclusions of superficial observation on some the points herein involved, that the summer of 1846 was de- d mainly to the examination of the comparative underground es of the various crops of our rotations. The comparatively

great depth and extent to which several of the leguminous crops (especially clover)—and also wheat and oats—penetrated, was very remarkable. It may be mentioned in passing, that of the specimens traced out in the experiments then made, one clover plant was for a length of time preserved with roots nearly 6 feet in length, the successful extrication of which, through their numerous wendings, was the result of the tedious labour of many days. It is to be regretted that the perfect series of specimens was not preserved as such, or at least perpetuated by drawings as a means of useful illustration for others.

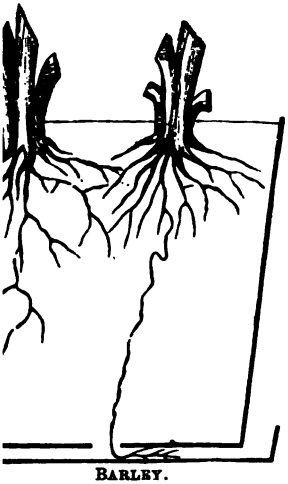
But to recur: when considering the results of field experiments on wheat, we have directed attention to the fact, that the success of the autumn-sown crop was greatly dependent upon the progress of the under-ground development during the early months of growth. It was held that this was very much favoured, other things being equal, by a liberal supply of available nitrogen within the soil, and that thus, the range of collection of the fibrous feeders of the plant was so extended as to render available, when needed in the after stages of growth of the plant, the mineral constituents of a much larger area of the soil, than otherwise would be the case. Very different are the usual conditions of the growth of barley. Instead of winter-growth, and a compressed soil, tending to increased depth and area of root distribution, we sow our barley in the spring, work the staple shallow, and keep it as light and open as possible. Under these circumstances of short time, rapid growth, and comparatively limited depth and area of root development, we find the direct supply of some of the rarer, but essential mineral constituents of our soils, much more efficient with the barley crop than with wheat.

The mechanical conditions of soil, and the season of growth of the barley crop, are in many respects more like those required by the turnip; and they are calculated to favour the distribution of a large amount of fibrous root near the surface, rather than any considerable development in the lower layers. In our paper on 'Turnip Culture,' * it was shown how much this distribution of surface root-fibres was increased by the use of superphosphate of lime. The same is the case with barley. It is obvious, that with this multiplication and more thickly distributed net-work of root-fibres, the greater must be the resources of the plant, within its comparatively limited period and area of growth. Thus it is, that the increased supply of certain important constituents within a limited area, enables the plant to provide itself more freely and rapidly with others it may require.

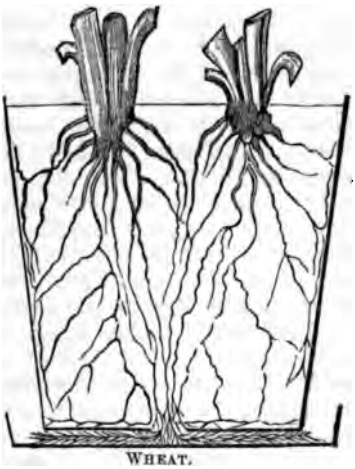
Whilst on this point it will not be out of place, in defect of

* Journal of Royal Agricultural Society, vol. viii., 1847.

ore pertinent illustrations, to quote some recent experiments, ıich wheat and barley were respectively grown in pots, but very different object from that in reference to which they are ıited. In these experiments the distribution of the roots of vo plants was so strikingly different, that when disinterred sketches of them were made, of which the following are :—



BARLEY.



WHEAT.

conditions under which these plants were grown, in pots, cover, and both during the summer months, were, it is true, artificial. Still the contrast here shown is pretty cha- stic of the plants as grown in our fields. These outlines ıerefore serve to fix the mind on the bearing of the points ıve been discussing. It may perhaps be further explained, vhilst in the case of the barley plant only one single fibril its way through the bottom of the pot, the wheat threw ıch a mass of ramifications that the whole of the surface of ish in which the pot rested was covered with a thick net- of roots ; as also was the bottom, and to a great extent the of the inside of the pot itself.

l referring to the action and province of mineral manures l to our crops grown on cultivated land, it has been shown mer occasions that, in a soil brought to what may be termed lition of *agricultural* exhaustion—that is, at the end of a n, when in the ordinary course of things it would receive e of some kind—the autumn-sown wheat was not increased oduce by the *direct* application of mineral manures, until ny crops had been taken from the land as to exhaust it of

mineral constituents more than would happen under century of ordinary rotation and home manuring. I been shown, that a very similar soil, certainly not more in an agricultural sense, gave an increase in the produce even on the first year's application of mineral manures. experiments in the same field, as well as those in oth very different, yet to a certain extent known history exhaustion or fertility, showed however, that miner were competent to yield, under these conditions of exhaustion, but a small amount of increase when com that obtained by nitrogenous manures. The evidenc led to the conclusion, that the mineral manures, if at increase in an extremely limited degree, unless there able nitrogen accumulated by some means *within the soi* that the increase of produce, other things being equal in proportion to such available nitrogen within the so any other supplied condition. It has, however, rec maintained in the Journal of the Royal Agricultur that our characteristic nitrogenous manures cannot be active in proportion to the nitrogen they contain.

Thus Baron Liebig states (Journal of the Royal A Society, vol. xvii. p. 298 *et seq.*) that ammonia alone acid alone, has never been used in agricultural experin he argues, that the acids in combination with ammonia niacal salts, and the bases in combination with nitric a nitrates, will have had their share in the results obtained of these salts; and that hence the value of such manu depend upon the amount of their nitrogen, but must the substances so combined with the nitrogen.

Before going on to Baron Liebig's further illustr arguments on the points here in question, it may be m reference to the above statements of fact, that we hav as the reader is aware, used ammonia in combination *bonic acid* only, with very marked effects. The late again, has given the account of his experiments in w acid, soda, and potash, were each separately used u In reference to these experiments, Mr. Pusey says— trials the nitric acid acted decidedly. The alkalies, neith produced even a trace of effect on the colour or on the the grass." And again—"The question being whether i the alkalies or the acid contained the active principl found upon a given soil the alkalies absolutely inoper the acid has acted exactly like saltpetre itself and like amm

It cannot for a moment be denied, that the state of c of the nitrogen in our nitrogenous manures, or their adm other substances, has some share of influence on the r

ive clearly shown that they have an influence, fluctuating according to season, exhaustion, amount employed, and other circumstances. It is, however, entirely inadmissible to attempt to draw any conclusions as to the influence of the state of combination of the nitrogen, or of the effect of substances supplied with it from the comparison of the results of experiments in which equal quantities of nitrogen are employed to a given area, or which were made indiscriminately in the same or in different seasons. Every one at all conversant with field experiments, will have been early impressed with the very varying proportional effect from one and the same manure, if used in different quantities in the same season, in even equal quantities in different seasons, but above all, in unequal quantities in different seasons. But Baron Liebig founds his arguments upon the influence of the varying chemical combination of nitrogen, and upon the comparative effects of ammoniacal salts used *alone*, or in admixture with other constituents, upon experiments with nitrogen in these different states, made indiscriminately with different quantities of nitrogen to a given area, and in different seasons.

He compares together on this point—the increase by the use of sal-ammoniac *alone*, for one year, 1843, with that during three other years (1844, 1845, and 1846), by sal-ammoniac and phosphates applied in the first and third years only, and with that during the same three years (1844, 1845, and 1846) by guano applied only in the first (1844). The amounts of nitrogen supplied to a given area were also widely different. They were respectively 70·3 parts when the sal-ammoniac was used alone, 176 parts when it was used with phosphates, and only about 15 parts when the guano was employed. Nor is anything said of the influence of the varying seasons; to which his authority, Mr. Kuhlmann, calls particular attention. In this way, the increase being first calculated for a fixed amount of nitrogen in manure in each case, Baron Liebig arrives at the following varying result of the given amount of nitrogen as attributable to different states of combination, or to admixture with other manurial constituents :—

NITROGEN IN MANURE.	Yielded Increase of Produce.
100 parts in the form of Sal-ammoniac	2,439 parts of Hay.
" " " Sal-ammoniac with phosphate of lime	4,367 " "
" " " Guano	16,460 " "

No reader of the Royal Agricultural Society's Journal will require to be told, that the results of about 70 parts of nitrogen to a given area in the form of sal-ammoniac alone in one year (1843)—of about 176 parts in the form of sal-ammoniac with

phosphates applied partly in 1844 and partly in 1846, and the increase of produce taken over three years (1844, 1845, and 1846) —and of about 15 parts of nitrogen in the form of guano applied only in 1844, and the increase taken over 1844, 1845, and 1846— are utterly incomparable with one another on the point here in question.

It should be mentioned with regard to the inferior result of a given amount of nitrogen as sal-ammoniac and phosphates, when compared with that in the form of guano, that Kuhlmann particularly stated that his crop by the former was in the first year (both hay and aftermath) so over-luxuriant from excess of manure, that it was necessarily cut before the proper time to prevent its rotting at the bottom.

With regard to the guano again, Kuhlmann states it to have contained 4·98 per cent. of nitrogen; but from the form of statement it does not seem clear whether this estimate was founded upon the analysis of the particular sample employed. As it is described as *Peruvian* guano, and also on account of the result, it is probable that the amount of nitrogen supplied in the guano was considerably greater than that assumed. After throwing out this observation, we of course, take the results as apparently intended by M. Kuhlmann, and as quoted by Baron Liebig. But Kuhlmann gives two experiments, side by side, with the very same guano. The one supplied, according to his estimate, in round numbers, 15 parts of nitrogen to a given area, and the other 30 parts; but it is the result of the *smaller* amount only (15 parts), which Baron Liebig cites to compare with the 176 parts in the sal-ammoniac with phosphates. The comparison of the effects of a given amount of nitrogen in guano, used in the *single* and in the *double* quantity to a given area, is as follows :—

Nitrogen in Manure.	Yielded Increase of Produce.
100 parts in the form of Guano, when 300 * parts of were employed	16,460 parts of Hay
100 parts in the form of Guano, when 600 * parts of were employed	9,566 " "

Here then, a given amount of nitrogen in the form of combination and admixture of the very same guano, its action being taken over exactly the same seasons, gave 72 per cent. more increase when used in the smaller than in the larger quantity. Yet it is the action of the smaller quantity applied in one year, and acting over three, which Baron Liebig selects to contrast

* For the convenience of round numbers we, with Baron Liebig, have assumed the guano to contain 5 per cent. of nitrogen instead of 4·98 per cent. as given by Kuhlmann.

:he large amount of nitrogen applied in different seasons in :her manures, attributing the difference in the result to the of the associated mineral constituents.

er adducing (with some other) experimental evidence of ind, Baron Liebig says :—

the use of the phosphate of lime, the effect of the ammonia in sal-iac was almost doubled. By the action of the substances which in accompany the ammonia, the effect of the latter was made seven times : than that of the same quantity in the shape of sal-ammoniac alone."

also adds as a general conclusion, that—

ice the effect of a manure is not proportional to the quantity of nitrogen ains, it will be easily understood why the value of a manure cannot be ted by its percentage of nitrogen."

will be instructive to examine a little further Baron Liebig's ing upon experimental evidence. Further illustrating the of the mineral constituents, he says :—

hlmann had manured a portion of his field in 1844 with a mixture of . of sal-ammoniac, along with phosphate of lime, and had obtained an of produce=12,172 lbs. of hay per hectare. In the same year the ı manured with 500 lbs. of sulphate of ammonia (without phosphate s) yielded an excess=3488 lbs. of hay. The former, therefore, yielded s more excess of produce than the latter."

e, be it observed, Baron Liebig compares the effect of 176 of nitrogen *with phosphates*, with that of 101½ lbs.* *without ates*, to illustrate the influence of these phosphates. He —

the addition of phosphate of lime to the ammoniacal salt the effect latter was augmented: there were obtained in all 8684 lbs. of hay han by the use of ammoniacal salts alone. Now, in this excess, which l to 2½ times the whole excess obtained by the ammoniacal salts alone, were contained 2¼ times more silica, and 2½ times more potash, than have been removed from the soil *without the use of phosphate of lime vith the ammoniacal salts*;† and the soil was rendered necessarily by h the poorer in these constituents."

is then, although there were 74½ *lbs. more nitrogen supplied the phosphates*, Baron Liebig attributes the 8684 lbs. of se to the addition of the phosphates. But he continues :—

is great loss of indispensable constituents could not be without influence subsequent crops. The field which in 1844 had been manured with s. of sulphate of ammonia had no manure in 1845, and received, in 00 lbs. of the same ammoniacal salt. The result was as follows :— me quantity of phosphate of lime and sal-ammoniac, which in 1844 elded a produce higher by 8684 lbs. than that of the field manured ulphate of ammonia alone, yielded in 1846, 3592 lbs. of hay. *The anured with sulphate of ammonia alone yielded, in* 1846, 3726 *lbs. of hat is,* 124 *lbs.* (134) *more than the other.* The same manures which

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e here take the composition as given by Kuhlmann for the pure salts, as Liebig has done the same. Kuhlmann states, however, that a deduction er cent. should be made for water and impurity.

ie italics are our own.

in 1844 had produced an enormous increase, and to which the unscientific and ignorant farmer would certainly, on account of this result, have attributed a preponderating value, lost, in 1846, their effect, although applied in the same quantity, and in the same proportions, to the same soil: and they lost their effect in the subsequent years, *in the same degree* * as they had at first produced a favourable result. The increased produce of the first year determined the diminished produce in the second and third years."

Here then, the deficiency of only 124 lbs. (134) of hay on the sal-ammoniac and phosphate plot in 1846, is attributed to its larger produce by 8684 lbs. in 1844. Further, this large increased produce in the first year, is said to determine the diminished produce in the "second," as well as in the third year. Baron Liebig does not quote the produce of the second year; but on reference to Kuhlmann's Paper, it is found that, instead of a "diminished" produce in the "second" year on the plot yielding the 8684 lbs. more increase than the sulphate of ammonia in 1844, that plot gives 240 *more* hay than the latter in the "second" year, 1845, when both were unmanured. Lastly, having omitted to quote the result of the second year, 1845, which was contrary to that stated, Baron Liebig speaks of the excess of 8684 lbs. of hay by the sal-ammoniac and phosphates in the first year, 1844, as the cause of the defect by the same manure of only 124 lbs. (134), in the third year. He treats these amounts as equal, thus—"they lost their effect in the subsequent years, *in the same degree* as they had at first produced a favourable result." Or, if the meaning were, that the sal-ammoniac and phosphates should, again, in 1846, have given 8684 lbs. more increase than the sulphate of ammonia, and that in this sense, the loss of effect was equal to the previous gain, this argument even, is quite inadmissable, as the comparative productive characters of the seasons are not taken into the calculation.

It is presumed that the best and only refutation needed, of the applicability of such evidence, and such reasoning, to establish the points in question, is to put them clearly before the reader.

How far it be really the case, that the inefficiency of the unrecovered supposed residue of nitrogen after the application of a nitrogenous manure, is due to the excessive exhaustion of mineral constituents, under the influence of the portion active and recovered—it requiring the peculiar action of additional salts of ammonia to set mineral constituents free and available—may perhaps be judged of by the results recorded in the foregoing pages, on the growth of barley after 10 years of turnips differently manured. During the growth of the 10 turnip crops, some of the plots had received every year enormously more of all the mineral constituents of the barley crop, except silica, than the turnips removed. The latter

* The italics here are our own; those in the earlier part of the paragraph are Baron Liebig's.

ioved no silica. So that, besides the excess of other mineral stituents, there was an accumulation during 10 years of avail- e silica. Yet with all this unusual accumulation of the essary mineral constituents, the residue of nitrogen unre- ered in the increase of the turnip crops—amounting as it did in e cases to more than the largest dressing we ever applied in year to a corn crop—gave us, where there was the largest unt thus unrecovered, during 3 successive years of barley, an age annual increase of only $5\frac{3}{4}$ bushels of corn, and between and 400 lbs. of straw, per acre. On the other hand, the ition of fresh nitrogen, in the form of salts of ammonia and ate of soda respectively, gave at once an increase of 33 and 35 els of corn, and 2982 and 3384 lbs. of straw. And although addition of the fresh nitrogen in the form of ammoniacal s yielded an increase of 33 bushels of corn and 2982 lbs. of w, which together would contain only about half the nitrogen plied in the manure, yet the remaining half, notwithstanding still enormous excess of previously supplied mineral consti- nts, gave in the succeeding year only $6\frac{3}{4}$ bushels increase of corn 300 lbs. of straw. Are we then to conclude, that under the cir- stances stated, the supposed large residue of nitrogen supplied the turnips, was inefficient only for the want of available mi- als?—and that the striking effects of the newly supplied lesser ounts of nitrogen were chiefly due to the action of the acids of ammoniacal salts and of the soda of the nitrate, in rendering ilable the otherwise locked up mineral constituents within the l? The utter inefficiency of even a liberal *direct* supply of neral constituents, to recover, in the second crop of wheat after trogenous manures, more than an insignificant proportion of e supplied nitrogen not recovered in the first, has been forcibly strated in a former paper.

This brings us to a consideration of the experimentally ascer- ined proportion of nitrogen used in manure, which has been ecovered in the increase of crop obtained. Before recording ur own direct evidence on the point, as illustrated in the experi- ents with nitrogenous manures on barley which form the chief bject of this paper, it will be well to say a few words on some vidence and reasoning recently put forth on the subject by thers, in this Journal.

In the article already alluded to (Jour. Roy. Ag. Soc., vol. vii., Part I.), Baron Liebig adduces evidence and arguments show, that, when the necessary mineral constituents are mixed ith the nitrogen in manure, there is no *deficiency*, but a *gain* of itrogen in the increase of crop. Assuming the increase of hay Kuhlmann's experiments to contain 1 per cent. of nitrogen, aron Liebig states that, where ammoniacal salts were used *alone*, ere was an apparent loss of four-fifths or three-fourths of the

nitrogen employed. He then quotes an instance to prove that, where mineral constituents were also added, there was no such loss, but a gain from natural sources.

Below, we give the instance quoted by Baron Liebig as showing a *gain*, by the side of two other of Kuhlmann's experiments, which he does not quote on this point; but in both of which *mineral constituents were also employed.*

	Nitrogen in Increase for 100 in Manure.	Per cent. Nitrogen Increased or lost in Manure
1. Liebig's example of 15 parts of Nitrogen with Phosphates, in Guano, applied in one year, and acting over three years	164·60	+64%
2. 30 parts of Nitrogen with Phosphates in the form of Guano, applied in one year, and acting over three years	95·66	—4·34
3. Sal-ammoniac containing 176 parts of Nitrogen with Phosphates, applied in the first and third years, and acting over the three years	43·67	—56·33

The result is then, that the only instance where there is an apparent gain was, where the practically speaking utterly insignificant amount of nitrogen in the form of guano, was used in one year, and the increase taken over that and the two succeeding years. Where Kuhlmann used only twice the amount of the very same guano, there was according to Baron Liebig's own method of calculation, a *loss* of more than 4, instead of a *gain* of 64 per cent. of the nitrogen employed. Lastly, where sal-ammoniac was used, in amount containing from 11 to 12 times as much nitrogen as the small quantity of guano, but *equally with it containing phosphates*, there was on the same mode of calculation, an apparent loss of 56·3 per cent., or more than half of the nitrogen employed. According to Baron Liebig's own data then, and his own mode of calculation, the farmer, to attain the happy result of no loss of the nitrogen of his manure, must employ it in quantity which is utterly insignificant in any practical point of view.

It will be seen that in the foregoing comments, we have not at all attempted on our own behalf, to discuss what is the real bearing of the evidence which Kuhlmann's experiments supply. Nor have we time or space to consider further the facts of others on the present occasion. It seemed desirable, however, before recording our own data and conclusions, to direct attention to the applicability of the facts selected, and the reasoning upon them, in reference to the points now in question, which have recently been submitted to the readers of the Journal on such high authority as that of Baron Liebig. Still less can we stop

ere to do more than reiterate in a single sentence our assent to ıe palpable truism, that if the mineral constituents of our crops ɛ deficient they must be supplied. We have on other occasions o say nothing of the present paper), so fully illustrated the nportance of keeping up a liberal provision in the soil of the ineral constituents of our crops—and also so frequently shown ıe usual circumstances of their removal or return, and the re-uirements for their direct supply, under an ordinary course of ractical agriculture with rotation *as it is*—that we leave to the udgment of the reader, the pervading insinuation in the paper bove referred to, that in our views the essentialness of the supply f the mineral constituents is ignored.

The experiments quoted by Baron Liebig to show the propor-ion of nitrogen recovered in the increase of crop to that supplied n manure, were made upon hay. We hope to record our results elating to that crop in an early paper. It will then be seen, ow far facts relating to grass, when cut green, are applicable as he foundation of conclusions regarding a ripened cereal grain. On the present occasion we have only to show the proportion of itrogen recovered to that supplied in manure, in the experi-ments on the growth of *barley*.

Were we to have attempted the direct determination of the itrogen in every separate stock of the different nitrogenous manures used during the six years of the experiments in Hoos-Field, and also in the corn and straw produced each year on ach of the 20 plots (making as would be necessary, duplicate nalyses in each case), this would have involved from 500 to 500 such determinations; a labour which we could not undertake. As it is, the number of nitrogen analyses recorded in the follow-ing Tables amount to more than 100.

The percentages of nitrogen in pure sulphate and muriate of mmonia, and in nitrate of soda, are of course well known. As hese substances occur in commerce, however, a certain average llowance has to be made for moisture and impurities. In stimating the amounts of nitrogen supplied to the soil by their se, we have made a deduction from the amounts they contain in a state of purity, founded not on the analysis of each sample ctually employed, but on the experience of ourselves and others s to the average composition of the commercial salts. The xact amount of deduction thus made has been stated at page 36, nd it is more probably too high than too low. On this supposi-ion the amounts of nitrogen we have supplied in manure will be omewhat greater than has been assumed; and in this case, the umbers we arrive at to represent the proportion of the supplied itrogen, which is recovered in the immediate increase, will be n a corresponding degree somewhat too high. The other itrogenous manure employed, namely, rape-cake, will, according

to the estimate already given at pp. 36-7, most probably average below 5 per cent. of nitrogen. In the Table XVIII. the result is given both on the assumption of the above amount as a maximum, and of 4·1 per cent. as a minimum; rather above the mean between the two, would probably be very near the truth. It may be stated, however, that with the smaller percentage of nitrogen in the rape-cake, the 2000 lbs. of the manure employed per acre, would supply the same amount of nitrogen as the 400 lbs. of ammoniacal salts, and the 550 lbs. of nitrate of soda, used by its side.

In making the selection of the specimens of the *produce* to be analysed, the question arose—whether the results would bear a more general application if that of certain characteristic *individual* manures were taken?—or whether, omitting points of minor distinction, it would be better to endeavour to get the mean composition of the produce of *whole series* of plots, for each of the six years separately over which the experiments were continued? After consideration of the advantages and disadvantages of either partial course, the latter was adopted. The samples prepared for analysis were therefore as follows:—

1st. For each of the six years separately, a mixture of equal weights of the corn (and also the same of the straws), from each of the plots without nitrogenous manure. These comprised the unmanured plot, and those with respectively, the "Mixed Alkalies," the superphosphate of lime, and the mixed alkalies and superphosphate of lime together. The composition of these mixed samples, *grown without nitrogenous manure*, is taken to represent that of the produce yielded by the unaided soil and season resources of nitrogen in the several years.

2nd. For each year, a mixture of the produce (corn and straw separately), of each of the four plots where 200 lbs. of ammoniacal salts were employed per acre. That is, where this amount of ammoniacal salt was employed alone, or in addition to each of the three mineral manure conditions above referred to.

3rd. For each year, a mixture (corn and straw separately), from each of the four plots, with the otherwise unmanured or the same mineral manure conditions, where 400 lbs. of the ammoniacal salts per acre were used.

4th. For each year, a mixture (of corn and straw separately) from the produce where, in addition to the four above-mentioned standard conditions without nitrogen, 2000 lbs. per acre of rape-cake were employed.

5th. An equal mixture, for the five years together (corn and straw separately), of the produce during five consecutive years, by 275 lbs. of nitrate of soda per acre per annum.

6th. An equal mixture, also for the five years together (corn and straw separately), from the plots where double the amount, or 550 lbs. per acre per annum, of nitrate of soda were used.

These nitrogen determinations, which, counting the duplicates, de on each specimen, amount to more than 100, were all ducted in the Rothamsted laboratory, by Mr. John Masters; epting that here and there repetitions have been made by . Pugh, or Mr. F. A. Manning, for the purpose of confirmation. may be added, that the process adopted was that by burning h soda lime, and estimating by the so-called "titrir" or ametric method.

At the moment we are writing, the whole of the analyses ch our plan should include are not completed, and we fear t the Tables will even eventually show some blanks. Notstanding these, we shall still have the means of illustrating identally, by a very extensive series of comparative results, the uence of season and manuring on the *percentage* of nitrogen the barley crop. And, so far as the more special object of iry is concerned—namely, that of the relation of the nitrogen the increase of produce to that in the manure employed—we ll be enabled to provide for six consecutive seasons, and for e of them for several different characteristic conditions of nuring, the important data of—

1st. The amount of nitrogen per acre in the corn, the straw, l the total produce.

2nd. The increase in the amount of nitrogen yielded per acre corn, in straw, and in total produce), by the use of given rogenous manures.

3rd. The proportions respectively, of the nitrogen *recovered*, and *recovered*, in the increase, to a given amount (100 parts) pplied in manure.

The percentage and acreage results are given in Tables XVI., VII., and XVIII, respectively, as follows:—

In Table XVI. the mean percentages of dry matter, and the tual determinations of nitrogen (and their mean) in the dry atter, of both the corn and straw, of the different mixed samples scribed above. By the side of these points of *composition*, are ven some particulars of the *quantity and quality* of the produce alysed, for the study of the connection between them.

In Table XVII. similar particulars are given; excepting that ere the percentages of nitrogen are calculated upon the corn nd straw in their natural state of hydration. The percentages f nitrogen in this Table are therefore applicable to the produce s harvested.

Table XVIII. gives, besides the acreage amounts of the produce itself, the acreage amounts of nitrogen in the actual produce; the amounts in the actual increase; and finally, the proportions respectively, *recovered*, and *not recovered*, in the increase, for every 100 parts supplied in manure.

TABLE XVI.—SHOWING the MEAN PERCENTAGES of DRY MATTER, ACTUAL and MEAN of DETERMINATIONS of NITROGEN in the DRY in BARLEY CORN, and STRAW, grown in different Seasons, and by Manures, together with some particulars of the Quantity and Q the Produce analysed.

	PARTICULARS OF PRODUCE.				COMPOSITION OF CORN.				COMPOSITION OF
YEARS.	Total Corn and Straw per Acre, lbs.	Per Cent. Corn in Total Produce.	Per Cent. Dressed Corn in Total Corn.	Weight per Bushel of Dressed Corn.	Per Cent. Dry Matter.	Per Cent. Nitrogen in Dry. Experiment 1.	Experiment 2.	Mean.	Per Cent. Dry Matter.	Per Cent in Experiment 1.
SERIES 1.—Without Nitrogen in Manure (Means of Unmanured, and Plots 4, 5.										
1852	3531	46·1	91·5	52·3	78·62	1·66	1·65	1·65	84·32	0·43
1853	3754	46·7	91·4	51·8	79·97	1·53	1·62	1·57	88·38	0·53
1854	4640	46·5	95·5	53·7	81·56	1·42	1·41	1·41	82·24	0·37
1855	3950	50·1	95·6	52·7	81·45	1·47	1·47	1·47	83·39	0·38
1856	1957	47·7	89·0	47·9	81·87	1·74	1·72	1·73	84·09	0·52
1857	3619	51·8	95·8	52·8	83·08	1·57	1·57	1·57	82·03	0·47
Mean	3576	48·1	93·1	51·9	81·09			1·57	84·05	
SERIES 2.—With Ammoniacal Salts, giving per Acre about 41 lbs. Nitrogen (Me Plots 8, 9, 10, and 11).										
1852	4999	43·8	88·5	50·9	79·32	1·78	1·81	1·79	84·44	0·47
1853	5129	44·9	88·0	52·6	79·74	1·70	1·75	1·72	87·91	0·49
1854	7200	43·5	94·5	54·0	81·59	1·48	1·48	1·48	82·17	0·44
1855	5697	44·9	93·7	51·8	80·48	1·74	1·69	1·71	83·38	0·51
1856	3694	41·0	89·6	47·6	81·29	1·72	1·71	1·71	84·17	0·48
1857	5329	50·7	96·7	53·3	83·04	1·83	1·79	1·81	83·35	0·55
Mean	5341	44·8	91·8	51·7	80·91			1·71	84·24	
SERIES 3.—With Ammoniacal Salts, giving per Acre about 82 lbs. Nitrogen (Me Plots 13, 15, 16, and 17).										
1852	5561	44·6	88·1	49·9	80·12	2·00	*1·98	*1·99	84·31	0·67
1853	5620	43·5	88·9	51·4	79·83	2·02	*1·96	*1·99	86·87	0·89
1854	8127	41·7	91·6	52·6	82·02	1·84	*1·84	*1·84	82·01	0·61
1855	6678	39·4	92·9	49·9	80·14	2·07	2·08	2·07	82·75	0·71
1856	3008	35·6	85·8	46·8	82·29	1·99	2·00	1·99	83·90	0·63
1857	6524	49·1	95·6	52·8	82·93	2·18	2·10	2·14	83·90	0·65
Mean	6253	42·3	90·5	50·6	81·22			†2·00	83·96	
SERIES 4.—With Rape-Cake, giving per Acre 82·100 lbs. Nitrogen (Means of Plots 14, 18, 19, and 20).										
1852	4702	43·9	91·9	51·5	80·45	*1·82	*1·76	*1·79	84·68	*0·45
1853	5190	43·2	86·4	51·2	79·26	*1·84	*1·79	*1·81	87·55	*0·44
1854	8159	41·3	93·4	52·7	82·08	*1·75	*1·77	*1·76	82·86	*0·45
1855	6823	40·2	92·5	50·1	81·73	2·09	2·08	2·08	83·96	0·68
1856	5039	36·4	90·1	46·6	82·56	1·94	1·94	1·94	84·49	0·63
1857	7161	48·9	95·5	53·8	82·84	1·92	1·91	1·91	83·79	0·47
Mean	6177	42·3	91·6	52·0	81·49			†1·88	84·55	
With Nitrate of Soda, giving per Acre about 41 lbs. Nitrogen (Plot 7).										
1853-7	5226	45·2	92·7	51·9	81·63	1·70	1·70	1·70	84·47	0·46
With Nitrate of Soda, giving per Acre about 82 lbs. Nitrogen (Plot 12).										
1853-7	6198	43·0	91·9	50·9	81·71	2·01	2·00	2·00	84·87	0·64

* These figures refer to analyses made since the Paper went to Press for the Journ

† These *means* are necessarily amendments of the figures in the Journal, or addit case may be, in consequence of the supplementary analyses referred to in the note abov

TABLE XVII.—SHOWING the MEAN PERCENTAGES of DRY MATTER, and the PERCENTAGE of NITROGEN, in BARLEY CORN, and STRAW, grown in different Seasons and by different Manures; CALCULATED on their CONDITION of DRYNESS as HARVESTED; together with some particulars of the Quantity and Quality of the Produce analysed.

Years.	Particulars of the Produce.				Composition of Corn.				Composition of Straw.			
	Total Corn and Straw per Acre, lbs.	Per Cent. Corn in Total Produce.	Per Cent. Dressed Corn in Total Corn.	Weight per Bushel of Dressed Corn.	Per Cent. Dry Matter.	Per Cent. Nitrogen in Fresh.			Per Cent. Dry Matter.	Per Cent. Nitrogen in Fresh.		
						Experiment 1.	Experiment 2.	Mean.		Experiment 1.	Experiment 2.	Mean.
Series 1.—Without Nitrogen in Manure (Means of Unmanured, and Plots 4, 5, and 6).												
1852	3534	46·1	91·5	52·3	78·62	1·30	1·30	1·30	84·32	0·36	0·39	0·37
1853	3754	46·7	91·4	51·8	79·97	1·22	1·30	1·26	88·33	0·47	0·45	0·46
1854	4640	46·5	95·5	53·7	81·56	1·16	1·15	1·15	82·24	0·30	0·30	0·30
1855	3950	50·1	95·6	52.7	81·45	1·20	1·20	1·20	83·39	0·32	0·33	0·32
1856	1957	47·7	89·0	47·9	81·87	1·42	1·41	1·41	84·00	0·44	0·45	0·44
1857	3619	51·8	95·8	52·8	83·08	1·30	1·30	1·30	82·03	0·38	0·40	0·39
Mean	3576	48·1	93·1	51·9	81·09			1·27	84·05			0·38
Series 2.—With Ammoniacal Salts, giving per Acre about 41 lbs. Nitrogen (Means of Plots 8, 9, 10, and 11).												
1852	4999	43·8	88·5	50·9	79·32	1·41	1·44	1·42	84·44	0·40	0·40	0·40
1853	5129	44·9	88·0	52·6	79·74	1·36	1·39	1·37	87·91	0·43	0·45	0·44
1854	7200	43·5	94·5	54·0	81·59	1·21	1·21	1·21	82·17	0·36	0·33	0·34
1855	5697	44·9	93·7	51·8	80·48	1·40	1·36	1·38	83·38	0·42	0·43	0·42
1856	3694	41·0	89·6	47·6	81·29	1·40	1·39	1·39	84·17	0·40	0·41	0·40
1857	5329	50·7	96·7	53·3	83·04	1·52	1·49	1·50	83·35	0·46	0·45	0·45
Mean	5341	44·8	91·8	51·7	80·91			1·38	84·24			0·41
Series 3.—With Ammoniacal Salts, giving per Acre about 82 lbs. Nitrogen (Means of Plots 13, 15, 16, and 17).												
1852	5561	44·6	88·1	49·9	80·12	1·60	*1·59	*1·59	84·31	0·56	*0·49	*0·52
1853	5620	43·5	88·9	51·4	79·83	1·61	*1·56	*1·58	86·87	0·51	*0·49	*0·50
1854	6127	41·7	91·6	52·6	82·02	1·51	*1·51	*1·51	82·01	0·50	*0·48	*0·49
1855	6678	39·4	92·9	49·9	80·14	1·66	1·67	1·66	82·75	0·59	0·59	0·59
1856	5007	35·6	85·8	46·8	82·29	1·64	1·65	1·64	83·90	0·53	0·53	0·52
1857	6524	49·1	95·6	52·8	82·93	1·81	1·74	1·77	83·90	0·55	0·54	0·54
Mean	6253	42·3	90·5	50·6	81·22			†1·63	83·96			†0·53
Series 4.—With Rape-Cake, giving per Acre 82-100 lbs. Nitrogen (Means of Plots of 14, 18, 19, and 20).												
1852	4702	43·9	91·9	51·5	80·45	*1·46	*1·42	*1·44	84·68	*0·38	*0·41	*0.39
1853	5190	43·2	86·4	51·2	79·26	*1·46	*1·42	*1·44	87·55	*0·38	*0·43	*0·40
1854	5150	41·3	93·4	52·7	82·08	*1·44	*1·45	*1·44	82·86	*0·37	*0·38	*0·37
1855	6823	40·2	92·5	50·1	81·73	1·71	1·70	1·70	83·96	0·57	0·60	0·58
1856	5039	36·4	90·1	46·6	82·56	1·60	1·60	1·60	84·49	0·53	0·54	0·53
1857	7161	48·9	95·5	53·8	82·84	1·59	1·58	1·58	83·79	0·39	0·40	0·39
Mean	6177	42·3	91·6	52·0	81·49			†1·54	84·55			†0·45
With Nitrate of Soda, giving per Acre about 41 lbs. Nitrogen (Plot 7).												
1852-7	5236	45·2	92·7	51·9	81·63	1·39	1·39	1·39	84·47	0·39	0·38	0·38
With Nitrate of Soda, giving per Acre about 82 lbs. Nitrogen (Plot 12).												
1852-7	6198	43·0	91·9	50·9	81·71	1·64	1·63	1·63	84·87	0·54	0·49	0·52

* These figures refer to analyses made since the Paper went to press for the Journal.
† These *means* are necessarily amendments of the figures in the Journal, or additions, as the case may be, in consequence *of the supplementary* analyses referred to in the note above.

TABLE XVIII.—SHOWING, in Lbs., the FRESH PRODUCE per ACRE, the NITROGEN per ACRE in PRODUCE, the NITROGEN per ACRE in INCREASE by NITROGENOUS MANURE and the NITROGEN RECOVERED, OR NOT RECOVERED, in INCREASE, for 100 supplied in MANURE.

YEARS	Mean Produce per Acre, lbs.			Nitrogen per Acre, in Mean Produce, lbs.			Nitrogen per Acre, in Mean Increase, lbs.			For 100 Nitrogen in Manure.		
										Nitrogen Recovered in Increase.		
	Corn.	Straw.	Total.	Corn.	Straw.	Total.	Corn.	Straw.	Total.	Corn.	Straw.	Total.
SERIES 1.—Without Nitrogen in Manure (Mean of Unmanured and Plots 4, 5, and 6).												
1852	[illegible]	[illegible]	3524	21·16	7·05	28·21						
1853	1754	[illegible]	3754	22·10	9·20	31·30						
1854	[illegible]	[illegible]	3640	24·83	7·44	32·27						
1855	1478	1362	2840	23·74	6·31	30·05						
1856	[illegible]	[illegible]	1657	13·15	4·51	17·66						
1857	1675	1744	3419	24·37	6·80	31·17						
Mean	1791	1785	3576	21·56	6·88	28·44						
SERIES 2.—With Ammoniacal Salts, giving per Acre about 41 lbs. Nitrogen (Means of Plots 8, 9, 10, and 11).												
1852	2750	2800	5550	31·10	11·24	42·34	9·94	4·19	14·13	24·2	10·2	34·4
1853	2604	[illegible]	5429	31·52	12·41	43·96	9·42	3·24	12·66	23·0	7·9	30·9
1854	3131	3809	6940	37·88	13·83	51·71	13·05	6·39	19·44	31·8	15·6	47·4
1855	2587	[illegible]	5579	27·34	13·17	48·51	11·60	6·86	18·46	28·3	16·7	45·0
1856	1510	2170	3680	21·11	8·70	29·81	7·96	4·19	12·15	19·4	10·2	29·6
1857	2703	[illegible]	5329	19·54	11·82	52·36	16·17	5·02	21·19	39·4	12·2	51·6
Mean	2447	2900	5341	32·01	11·87	44·78	11·36	4·98	16·34	27·7	12·1	39·8
SERIES 3.—With Ammoniacal Salts giving per Acre about 82 lbs. Nitrogen (Means of Plots 13, 15, 16, and 17).												
1852	2750	3078	5828	*31·18	†10·00	†55·18	†14·32	* 8·95	†27·27	†22·3	†10·3	†32·6
1853	2443	3175	5620	*38·34	†15·87	†54·50	†16·53	† 6·67	†23·20	*20·2	† 8·1	†28·3
1854	3547	4784	8331	*51·23	*23·20	*74·43	*26·40	*15·76	*42·16	*32·2	*19·2	*51·4
1855	2610	3019	5678	43·64	23·89	67·53	19·90	17·38	37·48	24·3	21·4	45·7
1856	1741	2227	3968	29·21	16·78	45·99	16·06	12·27	28·33	19·6	14·9	34·5
1857	3242	3282	6524	56·67	17·94	74·61	32·30	11·14	43·44	39·4	13·6	53·0
Mean	2555	3078	6253	43·14	*18·95	*62·09	*21·59	*12·06	*33·65	*26·3	†14·7	†41·0
SERIES 4.—With Rape-Cake, giving per Acre 82·100 lbs. Nitrogen (Means of Plots 14, 18, 19, and 20).												
1852	2541	2857	5398	47·02	†29·72	†40·29	†40·01	† 8·56	† 3·21	†11·80	†10·4	† 3·9	†14·3
1853	2231	2946	5180	*42·31	†11·78	†44·09	†10·21	† 2·58	†12·79	†12·4	† 3·1	†15·5
1854	3307	4783	8150	*48·48	†17·70	†66·18	†23·65	†10·26	†33·91	†28·8	†12·5	†41·3
1855	2744	3451	6195	16·61	23·67	70·28	22·87	17·36	40·23	27·9	21·2	49·1
1856	1844	2826	4670	29·34	10·99	40·33	16·19	12·48	28·67	19·7	15·2	34·9
1857	3005	3656	7161	55·38	14·26	69·64	31·01	7·46	38·47	37·8	9·1	46·9
Mean	2620	3531	6177	*40·31	*15·78	*56·09	*18·75	*8·90	*27·65	*22·9	*10·5	*33·7
With Nitrate of Soda, giving per Acre about 41 lbs. Nitrogen (Plot 7).												
1853-7	2364	2862	5226	32·86	10·88	43·74	11·22	4·03	15·25	27·4	9·8	37·2
With Nitrate of Soda, giving per Acre about 82 lbs. Nitrogen (Plot 12).												
1853-7	2666	3532	6198	43·46	18·37	61·83	21·82	11·52	33·34	26·6	14·0	40·6

* These figures are amended statements of those given in the Journal, due to the supplementary analyses referred to in the foot-notes to Tables XVI. and XVII.

† These figures are entirely additions to the Table as given in the Journal, and are also due to supplementary analyses referred to in Tables XVI. and XVII.

From the extent to which our paper has already reached, as well as from the incompleteness of our Tables at the moment we are obliged to conclude for the press, we must forego the adequate consideration of the mass of important data they will provide, and content ourselves with giving some direction to the more careful study of the reader.

A few words should first be said, on the influence of season and manuring, upon the *percentage* of nitrogen in the produce of barley. And whilst on this point, we may refer the reader to a rather fuller, though still only summary, treatment of the effects of these agencies on the nitrogenous percentage of *wheat*, given in the 'Quarterly Journal of the Chemical Society,' vol. x., part i., April 1857. In the main, their direction and tendency are very similar with the two crops, though differing incidentally on certain points.

Referring to the influence of varying *season*, we find both the grain and straw, when grown without nitrogenous manure, to show a tendency to relatively low percentage of nitrogen, the higher the characters of the produce as indicated by general coincidence of high proportion and weight per bushel of corn, with comparatively full amount of crop per acre. It will be remembered that 1854, 1855, and 1857, were the best corn-yielding years, whilst 1856 was the worst. Accordingly, 1854 and 1855, show the lowest percentage of nitrogen in the corn, and also in the straw; 1856, on the other hand, gives the highest percentage in the corn, and about the highest in straw. On the average of the few seasons before us then, so far as the crops grown without nitrogenous manure are concerned—that is, those which ripened best—the tendency was to give the lower percentage of nitrogen, the higher the character of the crop, and *vice versâ*. The same was the case with wheat. But as with it, so with barley, the rule is not without exception, but would seem only to apply on the average, as our seasons go. The most striking exception in the Table before us is 1857; when, with an unusually favourable season for yield and maturation of corn, we had, compared with the other good years, a somewhat high percentage of nitrogen in both corn and straw.

Turning to the produce grown by nitrogenous manures, and again comparing season with season, the rule just indicated does not seem to be so clearly borne out. When, however, it is considered that the influence of the nitrogenous manures, even when used in the smaller of our adopted quantities, was to produce over-luxuriance, and to depreciate the proportion and quality of the grain—that is, to be unfavourable to the most perfect maturation—it will be seen, that an apparent exception under these circumstances, is rather a confirmation of the assumption that

high maturation and low percentage of nitrogen are generally, with the average of our seasons, coincident.

In further illustration of the adverse influence of too high manuring on the proportion and quality of the corn, and of the fact that the tendency of depreciation in the latter is to give a higher percentage of nitrogen, we may refer to the *mean lines* in Tables XVI. or XVII. It will there be seen that, on the average of the six years, all the enumerated characters of quality of produce, were lower where even the smaller quantity of ammoniacal salts was used, than where none at all were employed; and they were lower still with the larger amounts of them. And again, where the rape-cake was used the average qualities were intermediate between those by the larger and the smaller amounts of ammoniacal salts. The mean percentages of nitrogen, so far as the Tables provide them, are, on the view which has been assumed, entirely consistent with these indications. Thus, in both corn and straw, the mean percentage of nitrogen was lowest where no nitrogenous manure was employed—that is, where the average characters of quality of the produce were the highest. It was higher with the small amount of ammoniacal salts, and higher still with the larger amount; and with the rape-cake it was intermediate between the two. The same is borne out on comparing the characters and composition of the produce by the smaller, with those by the larger amount of nitrate of soda. With the smaller amount of nitrate, we have, taking an average of the five seasons, the higher proportion of corn, the larger proportion of dressed corn in total corn, and the higher weight per bushel of dressed corn, and with these higher qualities of produce, the lower percentage of nitrogen in both corn and straw.

That we should get the higher *qualities* of crop indicated with the lowest amounts of produce per acre, is perfectly consistent with the practically admitted fact, that the *sample*, particularly of barley, is, on the average, the better the smaller the amount of crop. This smaller amount of crop, is coincident with the relative deficiency of available nitrogen within the soil. And, with this higher quality of sample obtained with a low relative provision of nitrogen in the soil, we have a tendency to low percentage of nitrogen in the most valuable descriptions of the grain. But *quality* cannot in practice be bought at so great a sacrifice of *quantity*. And it is seen that, when we increase the *quantity of crop* by increasing the relative amount of available nitrogen in the soil, it generally depreciated in the admitted characters of *quality*: and at the same time the percentage of nitrogen is increased. Further, the tendency to diminished quality and increased percentage of nitrogen on the one hand, with increased amount of crop on the other, would appear to be the greater, the more excessive

supply of nitrogen beyond that which in the average of seasons can yield a well conditioned and healthily ripened crop. Barley indeed, from its comparatively limited hold on the soil, and its small and weakly straw in proportion to the weight of corn it has to carry, is, so far as favourable ripening and good sample are concerned, more sensitive to vicissitudes of season and to high manuring than wheat. And it is with the greater variation in degree of maturation in the former than in the latter, in one and the same season with different proportions of available nitrogen provided within the soil, that we have at the same time, a greater variation in the *percentage* of nitrogen in the produce depending on the manure employed.

Upon the whole it may be considered that, the percentages of nitrogen in our produce of barley grown without nitrogenous manure, were, for the soil and seasons in question, lower than they would be in the ordinary practice of farming, owing to a constant relative defect of nitrogenous supply for that amount of crop, which the soil and seasons were otherwise competent to bring to a practically sufficient degree of perfection. On the other hand, the figures in the Tables, taken together with the circumstances of growth and the characters of the produce to which they refer, would lead to the belief that, on the average of seasons, the percentage of nitrogen can be but little increased beyond the perhaps abnormally low amount obtained where the nitrogenous supply was obviously in defect, without at the same time a diminution in the practically admitted characters of high quality of the corn. In fact, it would appear probable, that we cannot, keeping within the limit of healthily matured full crops, increase the percentage of nitrogen in our barley grain much above a comparatively low amount, as our seasons go. Yet, the fact that in 1857, which was an unusually favourable season for the proportion and the ripening of the corn, we had a high percentage of nitrogen in the dry substance of that corn, supplies us for barley (as was found in the case of wheat*), with an interesting exception to any too wide an application of that which may nevertheless be taken as a general tendency, at least within the limits of our own locality and average climatic conditions.

It is owing to the great influence of vicissitudes of season upon the *condition* of the crop when harvested, that the percentages of dry matter in the produce, and especially of the straw, of our experimentally grown barley, have not the obvious connection with the other points of composition of the crop, that we should otherwise have expected. Adequately to discuss these variations in the percentage of dry matter, due to season and manuring,

* See Quarterly Journal of the Chemical Society, before referred to.

would require the record and coincident study of the *percentages of ash*, in that dry matter—of which unfortunately our series of determinations are at present too incomplete.

We pass on, therefore, after these few observations on the effects of season and manuring upon the *percentage* of nitrogen in the barley crop, to the application of the analytical results to determine the proportion of nitrogen recovered in the increase of crop, for a given amount supplied in manure. Table XVIII. supplies us with our data on this point.

A preliminary point of interest in this Table is, the information it affords of the amount of nitrogen annually taken from the land in the produce, where none was supplied in manure. The highest amount of nitrogen thus stored up from the unaided soil and season resources was in 1854, namely, 32¼ lbs. per acre: the lowest amount was 17½ lbs. in 1856: and the average annual yield, taking the mean of the 6 years, was about 28⅓ lbs. It may be mentioned, that this latter amount, is more than that annually deposited in rain and other aqueous depositions, in the forms of ammonia and nitric acid. Investigation, of which there is at the present time much going on in reference to this subject, has still to determine the source or sources of this annual excess of assimilated nitrogen, beyond that supplied in the combined form in the measured and analysed aqueous depositions. Whether it be due to exhaustion of previously accumulated nitrogen in the soil—to direct condensation by the latter of the nitrogenous compounds occurring in the atmosphere—to the formation of ammonia or nitric acid within the soil at the moment of the evolution by chemical changes of certain elements in the nascent state—to the accumulation of combined nitrogen from the atmosphere by the plant itself—or to its assimilation of the free nitrogen of the atmosphere—whether, or in what proportion, these several possible sources may take part in the result, is as yet a great problem open for solution?

For the convenience of round numbers, and to be sure of making full allowance for impurity in the manures employed, we have, as already stated more than once, assumed that the 200 lbs. of ammoniacal salts per acre (100 lbs. each sulphate and muriate), and the 275 lbs. nitrate of soda, respectively supplied 41 lbs. of nitrogen, equal 50 lbs. of ammonia, per acre. The double amounts, namely, the 400 lbs. of mixed ammoniacal salts, and the 550 lbs. nitrate of soda, of course each supplied, on the same calculation, 82 lbs. of nitrogen per acre, equal 100 lbs. of ammonia. The 2000 lbs. of rape-cake, on the lowest estimate, would supply 82 lbs. also, but more probably nearer 100 lbs. nitrogen per acre. Taking, as we have done, low rather than high estimates of the nitrogen supplied in the various manures, it is obvious that the

ıount represented in the Tables as *unrecovered* in the increase crop, will be under rather than over stated.

It has been seen, that the average annual produce of nitrogen the barley crop was, without nitrogenous manure, from 17½ to ½ lbs. per acre per annum, giving an average of about 28⅓ lbs. ıe Table further shows that, when at least 41 lbs. of nitrogen ıre annually added per acre, in the forms respectively of ammoıcal salts and nitrate of soda, we obtained an average annual ıcrease of nitrogen in the crop of about 16½ lbs. when the ammoıcal salts were used, and about 15¼ lbs. when the nitrate of da was used. Again, when double the amount, or at least 82 ı. of nitrogen per acre, per annum, were added, we recovered ıen it was given in the form of ammoniacal salts about 33⅜ lbs., ıd when as nitrate of soda, about 33½ lbs., in the increase of crop. ıstly, by from 82 to 100 lbs. of nitrogen annually supplied in e form of rape-cake, we got back, taking the average of the ıt three years only, not quite 36 lbs. in increase.*

If, instead of stating the actual *acreage* amounts as above, we present the *proportion* of nitrogen, recovered or unrecovered in ıe increase, *for* 100 *parts supplied in manure*, the result is as llows. Where about 41 lbs. of nitrogen were added per acre, ır annum, in the form of ammoniacal salts, we get back in the crease, on the average of six years, 39¾ per cent. of the amount ıpplied; there are unrecovered therefore, about 60¼ per cent. of ıe so supplied nitrogen. When about the same amount of itrogen was supplied in the form of nitrate of soda, the average five years shows 37¼ per cent. recovered, and 62¾ per cent. ɔt recovered, in the increase. It will be remembered, that it was ı these instances, where there is seen to be an average of 60 per ınt., or rather more, of the supplied nitrogen unrecovered in the ıcrease, that we had a far better yield of increased produce of corn ıd straw for a given amount of nitrogen supplied in the manures, ıan where the larger amounts of the latter were employed. It ı worthy of remark, that, notwithstanding the far higher propor-

* By the aid of the analyses of the produce of the first three years by rape-ake, which were made since this Paper was printed off for the Journal, we st, taking the whole six years, an annual average of only 27⅞ lbs. nitrogen ı increase; instead of nearly 36 lbs., taking the last three years only. It ould appear probable that, although there was more nitrogen annually ıpplied in the rape-cake, than in the large amount of ammoniacal salts, here was less of it freed from existing combinations, and available, in the arly years, and hence a greater accumulation for the later. The rape-ake series, gave less average total produce (corn and straw), than the mmoniacal salts, in the earlier years; but gradually increased in effect in roportion to them, until in the last year, it gave nearly as much *excess* over hem, as in the first it had shown relative deficiency Thus, of average total pro-ıce (corn and straw together), the rape-cake series gave—in the first year 59 lbs. *less*; in the second, 480 lbs. *less*; in the third, 23 lbs. *more*; in the ourth, 145 lbs. *more*; in the fifth, 31 lbs. *more*; and in the sixth, 637 lbs. *ore*, than the double amount of ammoniacal salts.

tion of increase of corn and straw, for a given amount of nitrogen in these manures, where the smaller quantity of it was employed, we have, where the larger amount was used, also the larger *proportion* recovered in the increase. Thus, instead of 39·8 per cent. recovered, and 60·2 per cent. unrecovered, as with the smaller amounts of nitrogen in the manure, we have with the 82 lbs. of nitrogen per acre in ammoniacal salts, rather more, or 41 per cent. recovered. Again, the larger amount of nitrogen given as *nitrate of soda*, taking the average of five years, afforded 40·6 per cent. recovered in increase, by the side of only 37·2 per cent. when half the amount of the nitrate was employed. On the other hand, taking the rape-cake to have supplied only its minimum amount of nitrogen—that is, the same as the larger amounts of ammoniacal salts and nitrate of soda—it will even then have returned the least proportion of any, namely, 33·7 per cent. Assuming, however, that the 2000 lbs. of rape-cake supplied its maximum amount, or 100 lbs. of nitrogen per acre, then the return would be only 27·6 per cent. of the supplied nitrogen. The probability is, that the average amount supplied was very nearly the mean between the two; and, in that case, the *average* proportion of nitrogen returned in increase, for the supplied in rape-cake, will still be considerably lower than the obtained when either the ammoniacal salts or the nitrate of soda were employed.*

The fact is, that (excluding the rape-cake), the average percentage of the supplied nitrogen, which was recovered in the increase was rather greater where the excessive amounts of nitrogen were supplied in manure, which gave over-luxuriant and damaged crops and a less amount of increased produce for nitrogen supplied. This result, of the larger proportion of supplied nitrogen recovered, where the amounts in manure were excessive, is obviously, due to the much higher *percentage* of nitrogen in the produce, under these circumstances. It has been seen, that an increased percentage of nitrogen by the use of it in manure is, beyond a comparatively narrow limit, most probably accompanied with a depreciation in those qualities which in practice give high rate of value to the corn. This applies more particularly where the demand is chiefly for malting purposes. Upon the whole then, the slightly larger proportional return of nitrogen in increase for nitrogen supplied in manure, where the larger amounts of the ammoniacal salts and nitrate were employed, but a very questionable advantage.

The general result is seen to be that, in the experiments in question, when the nitrogen supplied in manure was the less e

* In the first two years of the large supply of nitrogen in rape-cake, the were scarcely 15 per cent. recovered in the immediate increase. In connexi with this point, see note at the foot of the preceding page.

, scarcely 40 per cent. of it was recovered in the increased
e of corn and straw obtained, taking the average of several
sive years. In some of the individual years there were less
30 per cent. of the supplied nitrogen recovered, and in others
; is, where the tendency to corn was the highest—there were
, or even over 50 per cent. recovered.

thus speaking of the proportion of the supplied nitrogen
red in the immediate increase of the barley crop, our form
tement must be understood as only representing the practical
, as measured by the difference between the amount of
en in the produce with nitrogenous manures, and in that
it them. It must be admitted, that we have not the means of
ng, whether or not the crop grown by nitrogenous manure,
similated the same amount of nitrogen from other sources,
t grown without it. We cannot say, therefore, whether the
as to render an account of more or less of nitrogen, than that
ted by the column of the amounts unrecovered in the
se of crop. The proportion unrecovered in the immediate
se is, however, obviously very large. It may be supposed
his at first unrecovered amount, is still available to after-crops ?
ay as alternatives assume—that a portion is locked up in the
1 a practically unavailable form ?—that it passes into states
nbination in which it can be drained away, or evaporated,
the soil ?—or lastly, that in some form or other it is got rid
the functional processes of the growing crop ? The actual
ative amounts of these several influences, science is not yet
) determine.

is obvious that, at any rate some of the apparent loss to
liate increase, of the supplied nitrogen, will be due to the
al distribution of the manure, in relation to the underground
s of the plant. If this were all, however, the unrecovered
en in a first crop, should be sooner or later available to those
follow. But one thing is certain ; that, even taking together
ncrease in several immediately succeeding after years, the
tion then recovered, of the previously unrecovered nitrogen,
ry much less than the *proportion* of the whole supplied,
is recovered in the year or years of its application. This
n the case when the provision of the necessary mineral con-
nts is very liberal. Indeed, a much less amount of nitrogen
supplied in the form of salts of ammonia or nitrate of
alone, will give a greater increase of produce than the
amount of supposed residual nitrogen, with direct mineral
res in addition. It cannot well be supposed, therefore,
he amount of the supplied nitrogen unrecovered, is simply
o its greater distribution, or to the exhaustion of mineral con-
nts, and that it still remains, and so far as state of combination
cerned, *is available.*

As a fact in practical agriculture, it must be concluded, that the nitrogen supplied in manure for full crops of grain, is not recovered in the increase within any moderate period of time. We hope on an early occasion, to add to the statistical results in this and in former Papers on other crops, those relating to the proportion of nitrogen recovered in increase, to that supplied in manure, for *grass*. But even with all the evidence which the facts of the field will be able to provide, the problem will still remain—of the exact explanations to be given by science, of the loss which is experienced by practice.

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REPORT

EXPERIMENTS WITH DIFFERENT MANURES

ON

PERMANENT MEADOW LAND.

BY

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nculus, or Crow-foot (various species); Luzula campestris,
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REPORT

OF

EXPERIMENTS WITH DIFFERENT MANURES ON PERMANENT MEADOW LAND.

Part I.—Produce of Hay per Acre.

The extent of land in this country in Permanent Grass, and the importance of the crop, both as regards its yield of food for animals, and its relations, under existing circumstances, to the crops under tillage, establish for it a high claim to investigation, with a view to increased productiveness. In several of its aspects—and in some involving its most intricate relations—the subject has received the attention of investigators at once comtent and laborious. The pages of the 'Journal of the Royal Agricultural Society of England' sufficiently bear out this statement. Among them are to be found valuable records of practical observation, and experience, as to the distribution, the adaptation, and the comparative utility, of the most important plants composing this heterogeneous crop, according to character of soil, climate, and other circumstances.* We have elaborate examinations by Professor Way, into the composition of the several plants, each grown under circumstances favourable to its development, and all taken as far as possible at an equal stage of growth.† And in Number xli. of the Journal will be found three Papers, each of distinctive value, bearing upon the practical management and manuring of the Grass crop.

As the title of the present Paper will indicate, its scope and objects are sufficiently distinct from those of the inquiries above alluded to. And, whilst the plan of the investigation which has been undertaken, and the character of the data which it has afforded, will necessarily lead to a somewhat special treatment of the subject, we shall endeavour, as far as circumstances will permit, to pay due regard to what appears to have been established hitherto.

An inquiry into the comparative effects of different manuring

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* See 'Prize Report,' by Mr. John Bravender, Jour. Roy. Ag. Soc., vol. 5.: Papers by Professor Buckman, Jour. Roy. Ag. Soc., vol. xv. p. 462; vol. p. 162; and vol. xvii. p. 513.

† Jour. Roy. Ag. Soc., vol. xi. p. 530, and vol. xiv. p. 171.

substances upon permanent grass, has, however, other grounds of interest than such as relate merely to determining the best means of increasing the gross amount of its produce. There is perhaps no crop more influenced in its *character*, as well as its *quantity*, by the attention bestowed upon it. Our Grass-crop comprises, as is well known, not only a great number of genera and species belonging to the *Graminaceous* family — the Natural Grasses commonly so called—but also various members of other families of plants, among which, by far the most important is the *Leguminous*. It so happens, then, that in our Meadows and Pastures there are associated, members of those two families of plants that afford us the crops which are not only the most important among those which enter into our rotations, but which, as there grown separately, and in alternation with one another, exhibit very characteristically different degrees of dependence upon the direct artificial supply of some of their constituents; and coincidently with this, show very distinctive relationships to one another in the course of cropping.

Thus, Wheat, Barley, and Oats, are of the *Graminaceous* family, and have, therefore, so far, their points of close relationship with the so-called "Natural Grasses." Beans, Peas, and the cultivated Clovers, Lucerne, &c., of our rotations, are, on the other hand, of the *Leguminous* family; and hence their relationship to the clovers, and allied plants, of our Meadows and Pastures. It is true, that the circumstances of growth, and the treatment, of the plants composing the mixed herbage of our Pastures and Meadows, are widely different from those of the allied plants—especially of the seeding ones—in our arable fields. In the one case, too, the plants are chiefly perennial, and in the other chiefly annual. It might well be expected, therefore, that, notwithstanding their natural alliances, crops which differ so widely both in certain comparatively incidental conditions of growth, and in some intrinsic qualities, should, at the same time, manifest somewhat different manurial requirements. In so far, however, as the influence of the different conditions, does not outweigh that due to the natural grounds of alliance or distinction among our agricultural plants, the effects of special manures, on the development of the different plants in our Meadows and Pastures, should afford interesting points of coincidence with those observed in regard to the allied crops grown in our Rotations.

In fact, among the most interesting of the points incidentally brought out by the experiments which form the subject of the present Report, is the striking confirmation which the results afford of the (so to speak) special adaptation, in a course of practical agriculture, of certain constituents of manure, to the

wth of certain of the crops of our rotations, accordingly as y belong to the one or to the other of the two great families of nts above referred to. That is to say, the comparative action lifferent descriptions of manure, upon the development of the erent plants of the mixed herbage of our Meadow, was found ccord with, and further to illustrate, points independently esta- ihed regarding the manurial requirements, and the mutual rela- is, of the plants of our rotations to which they are botanically ed. At the same time, independently of the difference in er conditions of growth and management, the permanent and alternating crops generally differ from each other so widely, h in regard to the amount of certain constituents which they pectively remove from the land, and to the proportion of these ch will probably be in due course returned in the home nures, that the character of the supplementary manures uired by even much allied crops, must obviously be some- it different in the two cases.

To turn to the experiments themselves: The plan adopted was, pply a number of different combinations of manuring sub- ices, each, year after year, to the same plot of land. And in er to provide proper standards of comparison, two plots were continuously unmanured, and another portion was annually nured with farm-yard manure.

The land selected comprised about 6 acres of the Park at hamsted, and it had been under permanent grass for certainly re than a century; indeed, for as long a period as is included in record that can be found relating to it. The general mode of tment for many years prior to 1851, was to manure occasionally h farm-yard dung, road scrapings, and the like; and sometimes h Guano, or other purchased manure. One crop of Hay was oved annually, amounting in weight to from 1¼ to 2 tons per e; and the second crop was always eaten off by sheep. In the ing of 1851, and again in that of 1852, 4 separate acres of the tted area were appropriated to the consumption by sheep of as ny lots of differently manured turnips; 10 tons of the roots being en upon each acre. Neither the 4 acres so appropriated, nor remaining 2, were manured in any other way in those two sons (1851 and 1852); nor were they manured at all in the e succeeding ones prior to the commencement of these ex- iments in 1856. It should be mentioned too, that the con- ption on the land of the different turnips did not in any case ease the produce over the 5 years, 1851–5 inclusive, by more n about 2 cwts. per acre annually. The land is a some- t heavy loam, with a red clay subsoil resting upon chalk;

and although it is not artificially, it is very well naturally drained. The area selected was perfectly level. Lastly, no fresh seed of any kind has been sown either within the period of the experiments, or for many years before it.

Early in 1856, 9 plots, of half an acre each, were measured off for as many different combinations of so-called *artificial* manuring substances; 2 of a quarter of an acre each, to be continuously unmanured; and 2, also of a quarter of an acre each, to be manured annually with farm-yard dung. In 1858, 4 additional plots, of one-sixth of an acre each, were appropriated to trials with nitrate of soda; the land so selected having been unmanured for several preceding seasons. The description, and quantities per acre, of the different manures employed, are given in the Tables, by the side of the results they yielded; but it will be well to state them here, at one view, a little more fully than there is room to do.

Plot 1. Unmanured.

Plot 2. Unmanured (duplicate plot at the further end of the series).

Plot 3. 2000 lbs. sawdust.

Plot 4. 200 lbs. each, sulphate and muriate ammonia (good samples of the salts so named in commerce).

Plot 5. 2000 lbs. sawdust, and 200 lbs. each sulphate and muriate ammonia.

Plot 6. 275 lbs. nitrate of soda.*

Plot 7. 550 lbs. nitrate of soda* (equal in nitrogen to the ammonium-salts of plot 4).

Plot 8. Mixed mineral manure, composed of—

200 lbs. bone ash ... ...
150 lbs. sulphuric acid (sp. gr. 1·7) } superphosphate of lime.
300 lbs. sulphate of potash.†
200 lbs. sulphate of soda.†
100 lbs. sulphate of magnesia.†

Plot 9. "Mixed mineral manure," as plot 8, and 2000 lbs. sawdust.

Plot 10. "Mixed mineral manure," as plot 8, and 200 lbs. each sulphate and muriate ammonia.

Plot 11. "Mixed mineral manure," as plot 8, 200 lbs. each sulphate and muriate ammonia, and 2000 lbs. sawdust.

Plot 12. "Mixed mineral manure," as plot 8, 200 lbs. each sulphate and muriate ammonia, and 2000 lbs. cut wheat-straw.

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* The experiments with nitrate of soda did not commence until the third season, 1858.

† The sulphates of potash and soda used, are the rough commercial article; the sulphate of magnesia, Epsom salts.

Plot 13. "Mixed mineral manure," as plot 8, and 400 lbs. each sulphate and muriate ammonia.
Plot 14. "Mixed mineral manure," as plot 8, and 275 lbs. nitrate of soda.*
Plot 15. "Mixed mineral manure," as plot 8, and 550 lbs. nitrate of soda* (equal in nitrogen to the ammonium-salts of plots 4, 10, &c.).
Plot 16. 14 tons farm-yard dung.
Plot 17. 14 tons farm-yard dung, and 100 lbs. each sulphate and muriate ammonia.

It would be desirable to have had some plots, with the superphosphate of lime, and the mixed alkali-salts, used separately; but it was considered, that to increase the number of the experiments, would be to extend the series beyond convenient practicable limits.

The artificial manures were, for the purpose of equal distribution, mixed with ashes prepared by burning soil with a portion of weeds and turf. They were sown broadcast. The date of sowing was, in 1856, the middle of February; in 1857, the 24th February; and in 1858, the 31st of March; excepting that the nitrate of soda (used in 1858 only) was not applied until the 8th of April. The farm-yard manure, and the sawdust, excepting in the first season, were put on in the previous November or December.

The first crop only, in each year, was mown; and the produce of each plot was weighed separately as *hay*, at the time of being carted to the rick. The second crop was eaten off by sheep having no other food; each plot, according to the bulk of its produce, having a given number penned upon a portion of it, the area being extended, day by day, as the feed was eaten down. To the further particulars of the feeding, and to the estimates made of the produce of the second crop, we shall recur presently.

The weight of hay (one cutting) taken from the different plots, in each of the 3 seasons, is given in Table I., p. 8.

Although the three seasons over which the experiments have extended differed widely one from another in climatic characters, the amounts of *gross produce*, under equal conditions of manuring, were upon the whole much the same in the three seasons. There was indeed a tendency to increase, from year to year, as the expe-

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* The experiments with nitrate of soda did not commence until the third season, 1858.

riments

Experiments with Different Manures on Permanent Meadow Land.

Table I.—Produce of Hay per Acre: tons, cwts., qrs., and lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum).	ANNUAL PRODUCE. 1856. Cut June 25; carted July 1.	1857. Cut June 23; carted Ju. 26-27.	1858. Cut June 26; carted Ju. 29-30.	Average of 3 Years.	Average Annual Increase or Loss by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	tns. cwt. qrs. lb. 1 2 1 23	tns. cwt. qrs. lb. 1 5 2 0	tns. cwt. qrs. lb. 1 2 0 8	tns. cwt. qrs. lb. 1 3 1 10	tns. cwt. qrs. lb. . . .
2	Unmanured (duplicate plot)	1 0 3 27	1 3 0 16	1 10 0 0	1 4 2 24	. . .
	Mean, or Standard Unmanured	1 1 2 25	1 4 1 8	1 6 0 4	1 4 0 3	. . .
3	2000 lbs. Sawdust	1 0 2 16	1 0 3 16	1 0 0 4	1 0 2 3	−0 3 2 0
4	200 lbs. each, Sulphate and Muriate Ammonia	1 15 3 24	1 13 2 22	1 15 2 6	1 15 0 8	0 11 0 5
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1 15 1 5	1 13 0 14	1 17 0 22	1 15 0 14	0 11 0 11
6	275 lbs. Nitrate of Soda*	. .	. .	1 6 1 12	. .	0 2 1 9
7	550 lbs. Nitrate of Soda*	. .	. .	1 11 3 8	. .	0 7 3 5
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure" †	1 10 2 13	1 12 2 26	1 16 1 22	1 13 1 2	0 9 0 27
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1 13 0 15	1 15 2 18	1 19 0 8	1 15 3 23	0 11 3 20
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2 16 3 7	2 17 1 10	3 4 0 4	2 19 1 16	1 15 1 13
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	2 16 3 13	2 17 1 16	3 1 2 4	2 18 2 11	1 14 2 8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	2 8 1 8	2 14 0 2	3 0 1 4	2 14 0 23	1 10 0 20
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	3 2 0 26	3 1 3 24	3 7 0 4	3 3 1 27	1 19 2 24
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda*	. .	. .	1 17 3 8	. .	0 13 3 5
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda*	. .	. .	2 10 1 6	. .	1 6 1 15
	Series 3.—With Farmyard Manure.					
16	14 tons Farmyard Manure	1 15 3 28	2 7 2 8	1 17 0 20	2 0 0 27	0 16 0 24
17	14 tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate of Ammonia	2 4 2 25	2 13 3 16	2 7 2 0	2 8 2 14	1 4 3 11

* The experiments with Nitrate of Soda were not undertaken until the third year (1858), and the land devoted to it had been unmanured during several preceding seasons.

† For further Particulars of these Manures, see page 6.

riments proceeded; but this tendency is the more apparent when the acreage amounts of *dry matter*, instead of gross produce of hay merely, are considered. Viewed in this way, the increase was moreover much greater in the second year as compared with the first, than in the third as compared with the second. It was too, perhaps upon the whole, the more marked where the most liberal manuring was employed, and the largest crops thereby obtained. On this point it should be remembered, that the manure from the sheep consuming the second crop, so far as it was due to the residual manures applied for the preceding first crop, would be so much addition to that supplied for the first crop of the succeeding season; and that the addition would be the greater, the more liberal had been the manuring, and the larger the amount of after-grass. It would too, with excess of manure, be somewhat cumulative, and relatively the more so, the more excessive the manuring, and the greater the produce of after-grass. The difference in the produce by the same manure, in one season compared with another—at any rate the increase in the amount of it in the second year of manuring over that in the first—cannot, therefore, be *wholly* attributed to differences in the characters of the seasons themselves.

With regard to the seasons themselves, a few general observations may nevertheless be made. The growing period of the first season, 1856, was generally much colder and wetter than that of either 1857 or 1858. Its rain was in April above the average, in May very large, and in the final month, June, but small. The moisture in the atmosphere, as indicated by the dew-point, was generally comparatively low; and with this, the range of temperature above that point was also low.

The grass season of 1857 ranged higher both in maximum and in minimum temperatures, and also in mean range, than that of 1856; and in that of 1858 higher numbers still were registered in regard to these several characters; but especially to that of the maximum temperature of the final month June, which in this third season, 1858, was very excessive. Both in amount and distribution of rain, April differed not very materially in the three seasons. May, as already mentioned, gave in 1856 a very large amount of rain, and also a large number of rainy days. In the same month of 1857, with at the same time much higher temperatures than in 1856, both the actual fall, and the distribution of rain, were very small. In May of 1858, again, with still higher temperatures than in the same month of 1856, both the actual amount and the distribution of rain were pretty full. In June, 1856, with again lower temperatures than in the other years, there was, after the very wet May, now but very little rain. In the warmer June of 1857 there was a fair amount of rain;

and in the still hotter June of 1858 there was, after a moderately wet May, but little rain.

The three seasons were therefore very different from one another, both in actual character as to heat and moisture, and in the mutual adaptations of these two qualities. As has been observed, however, the gross amount of the heterogenous produce —*hay*—did not differ very widely in the three seasons; though the acreage amount of *dry matter*, and consequently of carbon assimilated, was nevertheless notably less in the first and colder and wetter season 1856, than in either of the others. And, as will afterwards be seen, with the prevailing wet and cold of 1856, the percentage of dry matter in the produce was low, and that of the mineral matter, and of the nitrogen in that dry substance, high—characters which indicate comparatively backward conditions as to the stage of growth and the maturation of the plants. In a subsequent division of this Report we shall illustrate by pretty full detail on the point, the fact that the proportions of the different descriptions of herbage, as well as the character of the development of each, were very much affected, within equal periods of the season, according to the kind of manure employed. Had we equal means of deciding upon the varying character of the produce dependent on the varying character of the *seasons*, there can be little doubt, that the produce of these three very different seasons would show great differences, both as to the relative amounts of the various plants developed, and as to the character of the development of each.

Directing attention now to the comparative effects of the different *manures*, little more need be said as to the produce of the individual seasons. The results, as between one condition of manuring and another, will be both better and more easily traced by confining attention to the column showing the *average annual produce over the* 3 *years*, and to the concluding one of the Table (I.) showing the *average annual increase by manure*. These records relate, as will be remembered, to the produce of one cutting only. An estimate will be given further on, as to the actual and relative amounts of hay, to which the after-feed on the several plots was probably equivalent. At present it is only necessary to consider, how far the consumption of the after-grass upon the land, should influence the judgment to be formed of the effects of the different manures according to the weights of the produce of the first crop alone. On this point it may be remarked, that the knowledge we possess as to the average proportion of the nitrogen, and of the mineral matter, of the food consumed by stock, which they probably finally *store up* in their

bodies (and in the case of nitrogen exhale), is such as to lead to the conclusion, that the land would lose comparatively little of these manuring substances by the consumption upon it of the after-grass by sheep. By far the larger proportion of these contained in the second crop of one year would, therefore, remain towards the produce of the first crop in the succeeding year. Taken over a series of years, the annual produce yielded in the first crop, will thus pretty closely represent the average annual result of the manure on any particular plot; at any rate sufficiently so for a general comparison of the effects of one manure with that of another.

On one of the unmanured plots the average annual produce of hay was 1 ton 3 cwts. 1 qr. 10 lbs.; and it varied but little from year to year. The duplicate unmanured plot was somewhat shaded from the afternoon sun. It gave in the first two years about 2 cwts. less of hay annually per acre than the other, but in the third year as much as 8 cwts. of hay more. The fact was, as the result of the after-feeding showed, that this second plot, though it gave less mown hay in the first two years than the first plot, gave, on the other hand, more after-grass in those years. Hence, there was less removal from the land in the first two years; and, compared with the other plot, some accumulation of manuring matter for the first crop of the third season. The average annual yield of mown hay on the duplicate plot was, however, only $1\frac{3}{8}$ cwt. more than on the other. The mean result of the two plots may therefore be fairly taken as the average annual yield of the land and seasons in question. This amounted to 1 ton 4 cwts. and 3 lbs. of hay, as the *standard unmanured produce* of the experimental meadow-land.

Sawdust contains very little of either nitrogen or mineral matter; but, upon high authority, it has been stated to produce great effects as manure, by virtue of the solvent action of the carbonic acid which it yields in its decomposition, upon the mineral constituents of the soil. The plot where there were employed per acre annually 2000 lbs. of sawdust (containing 4 to 5 lbs. of nitrogen), yielded, however, an average annual produce of about $3\frac{1}{2}$ cwts. *less* hay than the unmanured land. Where 2000 lbs. of sawdust were employed *with ammonium-salts* (Plot 5), there were only 6 lbs. per acre per annum more produce than where the same description and amount of ammonium-salts were used alone (Plot 4). When the same amount of sawdust was added with a liberal mineral manure (Plot 9), the mixture gave annually about $2\frac{5}{8}$ cwts. more hay than when the same mineral manure (Plot 8) was used alone. Lastly, when the sawdust was employed in admixture with both the ammonium-salts and the

mineral manure (Plot 11), the produce per acre per annum was about ¾ cwt. less than when the same ammonium-salts and mineral manure (Plot 10) were used without the sawdust. The nearly a ton per acre per annum of organic matter rich in carbon, in the form of sawdust, was then practically of no avail.

As the previous enumeration (p. 6) and the Table (p. 8) show, the ammonium-salts employed, consisted of an equal mixture of the sulphate and the muriate of ammonia of commerce. This mixture is reckoned to contain about 25 per cent. of ammonia, which is equal to about 20·5 per cent. of nitrogen. The 400 lbs. of ammonium-salts per acre per annum, as used on several of the plots, would therefore bring annually on to the land about 100 lbs. of ammonia.

Where the 400 lbs. of ammonium-salts were used alone (Plot 4), they gave an average annual *increase* of 11 cwts. of hay. The average annual *produce* by the ammonium-salts was 1 ton 15 cwts. of hay.

The "*mixed mineral manure*" alone (Plot 8), which contained an ample supply of acid—phosphate, and sulphate of lime, and of potash, soda, and magnesia, in the form of sulphates, but which did not afford, in a direct manner, an increased supply of available silica, gave an average annual increase of about 9¼ cwts. of hay per acre.

The ammonium-salts alone, it has been seen, gave an annual increase of 11 cwts. of hay; only 1¾ cwt. more, therefore, than purely mineral manures. It will be shown, however, in some detail in a subsequent section, that the description of the increase differed extremely in the two cases. In fact, where the ammonium-salts were employed, the increase was exclusively due to the increased growth of *Graminaceous plants*—the so-called *Natural Grasses*—there being scarcely a *Leguminous* plant to be found upon the plot. Where the purely mineral manures were used, on the other hand, the *Grasses*, properly so called, were observed scarcely to have increased at all; whilst the whole plot was thickly covered with Perennial Red Clover (*Trifolium pratense perenne*) and some other Leguminous plants. Such a result is perfectly consistent with what has been before established regarding the (so to speak) characteristic adaptation of mineral and nitrogenous manures respectively, to those crops of the respective families which are grown in our rotations.

Mineral manures alone have then much increased the growth of the *Leguminous* plants on the meadow land. They enabled the *Graminaceous* ones, on the other hand, to assimilate but little more of nitrogen or carbon from natural sources, than did the normal supply of available mineral constituents in the unmanured

and. Very different was the action of mineral manures upon he growth of the Graminaceous plants of the Meadow, when hose manures were associated with a liberal artificial supply of *vailable nitrogen.* In the case of experiments both upon Wheat nd upon Barley, too, it has been shown that the land experi-ented upon was competent, for a series of years, to yield up nnually enough of mineral constituents for a considerably larger rop than could be grown under the influence of the annually vailable natural supplies of nitrogen alone. The annually vailable mineral constituents were, however, not sufficient for uch full crops as the seasons would yield, *when there was a iberal artificial supply of available nitrogen.* There appear to e obvious reasons, why this should be expected to hold good to a reater extent with Meadow Grass than with these Graminaceous rain crops. In land of pretty equal original characters, the mount of mineral matter taken annually from a given area in rass (mown for hay) is, under the same annual climatic cir-umstances, much greater than that taken off in the grain and in he straw of the seeding crop. The mechanical operations, and he exposure to the atmosphere, in the case of the arable land, ould appear to indicate a greater annual disintegration and iberation of total mineral constituents over a given area, though ot perhaps more within the limits of the immediately superficial ayers. In the case of Meadow Grass, therefore, the original haracters of the soil, and the seasons, being equal, both the nnual demand for mineral constituents would be greater, and the otal annual yield of them from the soil would be less, than in he case of the cereal crop.

Consistently with the foregoing considerations, it was found, hat although the ammonium-salts when used alone gave an nnual increase of only 11 cwts. of hay, the same amount of mmonium-salts, when in conjunction with the "*mixed mineral nanure*" (Plot 10), gave an annual increase of 1 ton 15⅜ cwts. f hay. Thus, the combination of ammonium-salts and the ixed mineral manure gave more than three times as much ncrease as the ammonium-salts alone, and four times as much s the mineral manure alone. The average annual produce, y the mixture of the ammonium-salts and mineral manure, mounted in fact to within less than a hundredweight of 3 tons f hay per acre, by the side of 1 ton 4 cwts. per acre on the ontinuously unmanured land.

Now, this produce, by the mixed mineral manure and ammo-ium-salts (Plot 10), consisted almost exclusively of *Grami-aceous* plants. There was scarcely a clover, or any other *Leguminous* plant, to be found upon the plot. The action of the

mineral manures, in this conjunction with ammonium-salts, was *not* therefore to yield increase by aiding the development of Leguminous plants, as was the case when the same mineral manures were used alone. The mineral manure has now acted by supplying, within the reach of the plants, a sufficiency of certain mineral constituents, to enable the Graminaceous plants to appropriate, and turn to the account of growth, a much larger portion of the *artificially supplied nitrogen* than they could do when the ammonium-salts were used alone. In fact, there were 1 ton 4¼ cwts. per acre per annum more *Graminaceous* hay grown, when the artificial supply of nitrogen was accompanied by a liberal artificial supply of certain mineral constituents, than when it was not so accompanied.

It has been shown, that the mineral manures had little or no effect in increasing the assimilation of nitrogen by the Meadow *Grasses*, when that constituent *was not artificially supplied*. On the other hand, they very considerably aided that assimilation, when available nitrogen *was artificially supplied*. It has also been shown, that the addition to the mixed mineral and nitrogenous manure of a large quantity of sawdust—a substance rich in carbon—did not further increase the produce. In fact, neither did the sawdust (whether alone or in admixture) seem to aid the solution of mineral constituents by the evolution of carbonic acid; nor did this possible source to the plant of carbonic acid itself seem to have been of any avail. The addition to the mixed mineral manure, and ammonium-salts of an equal weight of cut wheat-straw instead of sawdust (Plot 12), was equally without effect with that of the latter substance. Indeed, notwithstanding the large amount of mineral constituents, and especially of silicious compounds, contained in the cut wheat-straw, as compared with the sawdust, there was, whether compared with the produce by the mixed mineral and nitrogenous manure, or with that by the mixed mineral and nitrogenous manure and sawdust, an average annual deficit of 4 to 5 cwts. of first-crop hay, where the cut wheat-straw was employed. The plot with the cut wheat-straw, like the duplicate unmanured one, was, however, somewhat shaded; and like the latter, though it gave a somewhat deficient first crop, gave at the same time rather more after-grass than the plots most comparable with it. It remains to be seen, therefore, whether the less exhaustion by the first crop hitherto, and the greater return of constituents as manure in the consumption of the second crop, will not, before long, tell upon the amount of produce of the first crop. And, how far the inefficiency of both sawdust and cut wheat-straw was due to the slowness of their decomposition, will perhaps be apparent in the course of years.

The mixed mineral manures in conjunction with 400 lbs. per e, per annum, of ammonium-salts, gave an annual *produce* more than 2 tons 19 cwts., and an annual *increase* (over the nanured) of 1 ton 15⅜ cwts. of strictly *Graminaceous* hay. The ne mineral manures, together with double the above amount ammonium-salts, gave even more produce and increase still. e mineral manures and the double supply of ammonium-salts ve, on the average, 3 tons 3¾ cwts. of annual *produce*, and 1 1 19¾ cwts. of annual *increase*, of *Graminaceous* hay.

When we bear in mind the fact, that the mixed mineral nure alone scarcely increased the Graminaceous produce at all, would appear that the increase of such produce, upon the per-addition of the 400 lbs., or of the 800 lbs. of ammonium-ts, was (so far as its nitrogen was concerned) at any rate inly due to that which was thus *artificially supplied*. Assum-g this to have been the case, it would result that the first crement of 400 lbs. of ammonium-salts (=100 lbs. ammonia) lded an increase of 1 ton 15⅜ cwts. of hay, but that the ond increment of the same amount gave a further increase of ly 4⅜ cwts. The two together, as above stated, gave 1 ton ¾ cwts. of increase. As the nitrogenous supply was increased, e effect of a given amount of it was therefore very greatly ninished. Nor is this result to be attributed to a deficiency mineral constituents where the larger amount of ammonium-lts was employed. The produce on the addition to the mineral nure of the *smaller* amount of ammonium-salts, was indeed ite as heavy, if not heavier, than the soil and seasons were ited to mature advantageously. Further evidence on the point ll be adduced in a subsequent section of the Report. But it ay be here stated in passing, that the crop grown by the *larger* nount of ammonium-salts—supplying as it did the enormous antity of 200 lbs. of ammonia per acre per annum—was so er-luxuriant, as to be much laid, matted together, and dead at e bottom, some time before the bulk was ready for cutting.

It has been already stated that the trials with *nitrate of soda* ere not commenced until the last of the three seasons, over hich the other experiments extended. The nitrate too, was wn about a week later than the other manures. The result of is single season's trial with the nitrate was, that a given nount of nitrogen so supplied, did not increase the produce of y equally with the same amount in the form of ammonium-lts. Still the influence of artificial nitrogenous supply upon e Grass crop is here again illustrated.

Nitrate of soda, in amount supplying nitrogen equal to about) lbs. of ammonia per acre (Plot 6), gave scarcely any increase

whatever over the *mean* unmanured produce of the same season.* Double this amount of nitrate of soda (Plot 7), containing nitrogen equal to the ammonium-salts of Plot 4, gave about $3\frac{3}{4}$ cwts. less increase of hay per acre than the equivalent amount of ammonium-salts. When the smaller amount of nitrate of soda was used in conjunction with the "mixed mineral manure," the produce amounted to 1 ton $17\frac{3}{4}$ cwts. of hay, or to $11\frac{1}{2}$ cwts. more than when the same amount of nitrate was used alone. Lastly, with the larger amount of nitrate of soda (= in nitrogen to the 400 lbs. of ammonium-salts), together with the "mixed mineral manure" (Plot 15), there were 2 tons $10\frac{3}{8}$ cwts. of produce instead of 1 ton $11\frac{3}{4}$ cwts. by the same amount of nitrate of soda without the mineral constituents. This increased produce by the nitrate of soda and mineral constituents was, however, considerably less than either the average annual yield, or that of the third season taken alone, by an equal amount of nitrogen in ammonium-salts, with the mineral manure in addition. So far, however, as the action of the manures applied in such full quantity is cumulative from year to year, it will of course to that extent be illegitimate to draw any strict comparison between the produce of one manure in its third season, and that of another in its first season of application The character of nitrate of soda as an efficient Grass manure, and as acting, both on this and other crops, by virtue of the nitrogen it contains, is too well established by other experiments—indeed by common experience also—to admit of doubt. It remains to be seen, what will be the comparative effects of a given amount of nitrogen supplied in nitrate of soda and in ammonium-salts respectively, when the trials have been continued over numerous and various seasons.

Before leaving the results with the nitrate of soda, it should be stated that it had the same effects as the ammonium-salts, in discouraging the growth of the Leguminous herbage, and in encouraging that of the Graminaceous plants, or Grasses. The increase of action when the mineral constituents were added to the nitrogen in the form of the nitrate, was, therefore, as in the case of their addition to the ammonium-salts, *not* to be attributed to their enabling Graminaceous plants to take up more nitrogen *from natural or unaided sources*, but to their supplying, within a limited range of the soil, the mineral constituents requisite for the efficient action upon the collective and assimilative processes

* It will be remembered, however, that in this third season the duplicate unmanured plot gave an obviously somewhat excessive produce of hay; it having given smaller *mown* crops than the other in the preceding seasons, but more after-feed, and hence the condition of the land on the duplicate plot would be relatively somewhat too high for the third mown crop.

f the plants, of the *nitrogen artificially supplied.* It will be hown, on a future occasion, that the *percentage* of nitrogen in the lry substance of the hay, grown both by ammonium-salts alone, nd by nitrate of soda alone, was comparatively very high—in act, considerably higher than when the mineral manures were lso employed, whereby the Graminaceous produce was much ncreased. So far then as there was an excessive amount of itrogen, in the form of elaborated nitrogenous vegetable com- ounds, where the supplied nitrogen was liberal—the mineral onstituents in defect—and the growth restricted thereby—it was hat there is a relative deficiency in the formation of the *non-* itrogenous vegetable substances.

Attention has now been called to the annual amount of hay btained both without manure, and by the use of certain indi- idual, or classified constituents of manure. In this way, some nformation has been acquired as to the manurial requirements or the growth of a heavy produce of the crop in question. Let s now examine—what were the effects upon the hay crop of that omplex substance—*Farmyard manure?* And, bearing in mind he facts already brought to view, in regard to the action of cer- ain individual manures, let us endeavour to form a judgment as o which of the constituents, or classes of constituents, of farm- ard manure, its effects upon the hay crop are mainly, or at any ate characteristically, due.

The annual application of 14 tons of *farmyard manure* per cre, gave, over the three years, an average annual produce of 2 ons ¼ cwt. of hay, = 16¼ cwts. per acre per annum more than he unmanured plot. This increase by farmyard manure is reater than that by either the mixed mineral manure alone, or he ammonium-salts alone; but it is less than half the increase btained when these two descriptions of manure were used con- ointly. This increase of 16¼ cwts. of hay per annum, by the use f 14 tons of dung is, it will be seen, little more than 1 cwt. of ay for every ton of the manure employed.

It has been seen that *carbonaceous substance*, whether applied n the form of sawdust or of cut wheat-straw, had little or no ffect upon the hay crop. It is probable that the carbonaceous ubstance of the dung would yield up its carbon in the form of arbonic acid, or of other products of decomposition, more readily han that of either of the substances just mentioned. But the armyard manure contained, besides carbonaceous substance, a arge amount of both mineral constituents, and of ammonia, or itrogen in some form. It has been seen, too, that these latter ubstances, when used without carbonaceous matter, gave greatly ncreased crops of hay. Under these circumstances, we can ardly hesitate to attribute the main effects of the farmyard

manure upon the hay crop, rather to the conjoint action of its mineral and nitrogenous constituents than to its enormous bulk of carbonaceous substance.

That the *mineral* constituents of the dung had their share of effect, would appear from the facts, that the *Leguminous* herbage was moderately luxuriant on the dung plot, and that those of the *Grasses* were the most developed, which were increased in their proportion to the rest by the artificial mineral manures. And again, that the *nitrogen* also of the dung was effective, may be judged, not only from the general development of the Graminaceous plants under its use, but from the fact of a like fullness in the proportion of the Grasses *in flowering and seeding stem*, as where ammonium-salts were employed in conjunction with the mixed mineral manure. It would appear, however, that a much less proportion of the whole nitrogen supplied to the land was active, when it was provided in the form of farmyard manure, than when in that of ammonium-salts. There would, in fact, be considerably more of nitrogen applied per acre in the 14 tons of farmyard manure, than in the 400 lbs. of the mixed ammonium-salts. Nevertheless, the encouragement of the Leguminous plants was much greater, and that of the Graminaceous ones much less, where the farmyard manure was employed, than where the 400 lbs. of ammonium-salts, together with the mixed mineral manure, were used.

That the less produce by the farmyard manure, than by the mixed mineral manure and 400 lbs. of ammonium-salts, was due to a deficiency of *available* nitrogen, notwithstanding the large actual *amount* of it in the dung, would appear from the fact, that on the employment of 200 lbs. of ammonium-salts *in addition* to the farmyard manure (Plot 17), there was a further average annual increase of $8\frac{3}{8}$ cwts. of hay per acre. Still, even with this addition, there was about $\frac{1}{2}$ a ton less of hay annually than where the "mixed mineral manure" and the 400 lbs. of ammonium-salts were applied.

The evidence regarding the action of the *farmyard manure* goes to show, that, though it is doubtless a very complete and important restorer of both the mineral constituents and the nitrogen required to repair the exhaustion of this most greedy crop, yet, the amount of these constituents supplied by its means is proportionally much less active within a given time than that provided in the artificial combinations. As, however, permanent meadow-land, especially when attached to an arable farm, does not, as practice goes, so much as a matter of course, come in for a due periodic supply of farmyard manure as does the land under rotation, it becomes far more necessary in its case to bestow special consideration that the mineral constituents be not exhausted

Plot, Nos.	MANURES (Per Acre, per Annum).	Area of Plots.	1856 Sheep put on, Oct. 10.		1857 Sheep put on, Sept. 23.		1858 Sheep put on, Oct. 18		Number of Sheep kept for One Week per Acre.				Amount of Hay per Acre, per Ann. in the After-grass.*
			Number of Sheep	Number of Days Feeding.	Number of Sheep	Number of Days Feeding	Number of Sheep	Number of Days Feeding	1856.	1857.	1858.	Average Annual	
													lbs.
SERIES 1.—Without Direct Mineral Manure.													
1	Unmanured	Acre. ¼	10	13	8	13	10	12	74·3	59·4	68·6	67·4	1078
2	Unmanured (duplicate plot)	¼	10	17	10	13	10†	12	97·4	74·3	65·2	79·0	1264
	Mean, or Standard Unmanured		10	15	9	13	10†	12	85·8	66·8	66·9	73·2	1171
3	2000 lbs. Sawdust	¼	20	13	16	13	16	12	74·2	59·4	54·8	62·8	1005
4	200 lbs. each, Sulphate and Muriate Ammonia	¼	20	14	20	13	20	12	80·0	74·2	68·6	74·3	1189
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	¼	20	14	20	13	20	12	80·0	74·2	68·6	74·3	1189
6	275 lbs. Nitrate of Soda	¼	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
7	550 lbs. Nitrate of Soda	¼	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
SERIES 2.—With Direct Mineral Manure.													
8	"Mixed Mineral Manure"	¼	20	14	25	13	25	12	80·0	92·8	85·8	86·2	1379
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	¼	20	14	25	13	25	12	80·0	92·8	85·8	86·2	1379
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	¼	30	11	30	13	30	12	94·2	103·8	103·8	99·9	1598
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	¼	30	11	30	12	30	12	94·2	103·8	102·8	99·9	1598
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	¼	30	17	30	13	30	12	145·6	111·4	102·8	119·9	1918
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	¼	40	11	40	12	40	12	125·8	137·2	137·2	133·4	2134
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	¼	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	¼	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
SERIES 3.—With Farmyard Manure.													
16	14 Tons Farmyard Manure	¼	10	13	12	13	11	12	74·2	89·2	75·6	79·7	1275
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	¼	10	13	12	13	11	12	74·2	89·2	75·6	79·7	1275

* The calculation is made on the assumption that each Sheep would eat grass = 16 lbs. of Hay per week.
† One Sheep was taken from this plot to be killed when it had been only half the period feeding.

exhausted, than in that of rotation crops under ordinary good management. In fact, the grass-land of the arable farm is but too frequently looked upon as the legitimate sphere for robbery for the other crops. Indeed, considering the nature of the exhaustion of permanent grass-land generally, when mown for hay, and at the same time bearing in mind the character of the artificial manures, which are, in point of economy, at the command of the farmer, it would seem that the *permanent* condition of such land should be kept up by farmyard manure, stable dung, town manures, and the like, and the *active growth* aided, year by year, by the so-called artificial, nitrogenous—or, better still, nitrogenous and phosphatic—manures. Where hay is grown for the supply of a neighbouring town, the (in the above sense) permanent condition of the land is very generally maintained by town manures of some kind brought by the return carriage. But where hay is grown on an arable farm, and is mown for consumption by the stock (or, still worse, for sale), the return is but too often by no means so complete. The question of keeping up the fertility of grass-land by sewage, or other irrigation, is one of course of entirely separate consideration from that now before the reader.

Before giving a summary enumeration of the results and conclusions thus far indicated, it will be well to direct attention to the relative, and, as far as they can be estimated, the *actual* amounts of *after-grass* yielded, on the differently manured plots.

In TABLE II. are given :—

In the 1st Division—the actual number of sheep that were put upon each plot of after-grass, and the actual number of days they were fed upon it, in each of the three seasons of the experiments ;

In the 2nd Division—the number of sheep calculated to be kept per acre, on each plot for one week, in each of the individual seasons, and on the average of the three seasons ; and

In the last column of the Table—the estimated average annual amount of hay per acre, to which the after-grass consumed would be equivalent, reckoning the sheep to eat grass equal in amount to 16 lbs. of hay per head, per week.

Calculating the after-grass into its assumed equivalent of hay, as above described, the result is, of course, only an approximation to the truth. Looked upon as such, it is not without its value and interest. The so-estimated amounts of after-feed on the respective plots show, as compared one with another, relations very coincident, in general direction, with those indicated by the mown first-crops of hay.

It has already been noticed that the produce of first-crop hay on Plot 2 (the duplicate unmanured plot) was less in the first two seasons, and more in the third, than on Plot 1, the other unmanured one. Table II. shows, on the other hand, that there was rather more after-feed in the two first seasons on the duplicate unmanured plot than on the other. Taking the mean of the two plots, the unmanured land shows an average annual yield of after-grass = 578 lbs. of hay. The sawdusted plot, as in the first crop, so again in the second, gives rather less produce than the unmanured one. The ammonium-salts alone gave rather more after-feed than the unmanured plot; and the ammonium-salts and sawdust gave the same amount as the ammonium-salts alone. The Plot with the "mixed mineral manure" alone, with its luxuriant Leguminous herbage, gave more after-feed than the one with ammonium-salts alone. The addition of the sawdust to the "mixed mineral manure" gave no further increase. The Plot with both the "mixed mineral manure" and the 400 lbs. of ammonium-salts, as in the first crop, so now in the second, gave more produce than either of the plots where the respective manures were used separately. The addition of sawdust to the mixture of the two manures gave no further increase. The addition of cut wheat-straw, instead of sawdust, showed some advantage in the second crop, the produce in the first crop being somewhat deficient. The combination of the "mixed mineral manure," and the double amount (= 800 lbs. per acre) of ammonium-salts, gave the largest amount of first-crop hay, and now again the largest amount of after-grass, of any manure in the series.

The nitrate of soda, which was used only in the third season, and then yielded less of first-crop hay than an amount of ammonium-salts equal to it in contents of nitrogen, appears, according to the figures in the Table, to have given, on the other hand, a larger amount of after-grass. As, however, a large and equal number of sheep was put upon each of the nitrate plots, and *for one day only*, not even the relative amounts, still less the actual quantities recorded as estimated second-crop hay, can be much relied upon in these cases of experiment with the nitrate.

The farmyard manure plots gave of second crop, as they did of first, a produce intermediate between that without manure, and that by the "mixed mineral manure" and 400 lbs. of ammonium-salts.

Were these estimated amounts of hay in the second crop of the respective plots, to be added to those actually removed in the first crop, the *comparative* action of the different manures as it would be then represented, would not appear to differ in any material point from that indicated by the amounts of hay actually

taken off in the first crop. Independently of this, however, by far the larger proportion of both the mineral constituents and the nitrogen of the second crop would, as before stated, be returned to the land by the sheep feeding upon it. It would, therefore, obviously be a further deviation from the true representation of the actual facts, to take into account the estimated second crop as a part of the removed produce of the manures employed, than to omit it from the calculation altogether. These estimated amounts of second crop, varying as they do in the proportion of from 1 to 2, according to the manure employed, are, nevertheless, interesting of themselves, as showing great differences in vegetative activity after removal of the first crops, depending, of course, on the varying character and amount of the residual or unused manure. They are, moreover, useful aids in forming a judgment respecting the comparative cumulative effects, from year to year, of the different manures. But when, in a subsequent Part of this Report, we come to consider the debtor and creditor account of certain constituents on the several plots—the relation of the amounts removed in the produce to those supplied in manure—we shall assume the amounts taken off in the increase of the first crop only, as the most nearly representing the gain due to the supply in the manure employed.

It is proposed, in a subsequent section—to show the acreage amounts of certain constituents removed in the produce from the different plots, and the relation of these in the increase, to those supplied in the manures—to consider in some detail the varying description of the herbage according to the manure employed—and to show the consequent variations in the chemical composition of the complex gross produce, or *hay*. In the mean time, founded upon the evidence thus far recorded, relating to the amount per acre, and the general character, of the hay obtained by the different manures, the following general results and conclusions may be enumerated:—

1. That the effect of a mixed, but purely *mineral manure*, upon the complex herbage of permanent meadow land, was chiefly to develop the growth of the *Leguminous* plants it contained; and scarcely at all to increase the produce of the *Graminaceous* plants, or commonly called *Natural Grasses*.

2. That the action of purely *nitrogenous manures*, upon the permanent meadow, was to discourage the growth of the *Leguminous* herbage, and to increase the produce of the *Graminaceous* hay.

3. That by the *combination of both nitrogenous and proper mineral manures*, the produce of *Graminaceous* hay was very much

increased. In the particular soil and seasons in question, the increase obtained by the combination was far beyond the sum of the increase yielded by the two descriptions of manure, when each of them was used separately.

4. That *farmyard manure* gave a considerable increase of chiefly *Graminaceous* hay. In the soil and seasons in question, however, the artificial combination of nitrogenous and mixed mineral manure yielded a very much larger increase than an annual dressing of 14 tons of farmyard manure.

5. That peculiarly *carbonaceous manures* had little or no beneficial effect on the amount of produce of the hay. That the little effect (if any) which the carbonaceous manures did exhibit, seemed to be favoured by admixture with mineral manures; and then (as when the mineral manures were used alone) it appeared to be the Leguminous, rather than the Graminaceous herbage, that was encouraged.

6. That the beneficial action of *farmyard manure* upon the Grass crop, is to be attributed chiefly to its *mineral and nitrogenous constituents*, and comparatively little to its large amount of carbonaceous substance.

7. That the large increase of produce obtained by the *combination of nitrogenous and mixed mineral manure*, being almost entirely *Graminaceous*, the mineral manures, when in this combination, did not act as when used alone, in developing the highly nitrogenous *Leguminous* herbage. The great increase in the produce of hay obtained by the conjunction of the mineral with the nitrogenous manure, is to be attributed to the supply, within a limited range of the soil, of a sufficient amount of the necessary mineral constituents, to enable the *Graminaceous* plants to turn to the account of growth, *the nitrogen at the same time artificially supplied.*

8. The general result is, that the Leguminous plants in the *meadow*, like those grown in our *arable fields*, were much increased in growth, and assimilated more nitrogen from unaided sources over a given area, when they were liberally supplied with certain *mineral*, or *primarily soil-constituents*. At the same time, notwithstanding the high (both percentage and acreage) yield of nitrogen in Leguminous produce generally, the increased growth of the *Leguminous herbage of the meadow* was not favoured by the direct supply of nitrogenous manures—a result which is again very similar to that obtained with the *Leguminous crops of our rotations*. On the other hand, the Graminaceous *hay plants*, like the Graminaceous *grain-crops of our rotations*, assimilated but little more nitrogen, from natural sources, under the influence of liberal supplies of purely mineral manure; they gave a largely increased growth, only when there was an artificial

supply of *available nitrogen within the soil;* and when this was provided, the direct supply of mineral constituents was essential to its full effects.

The more practical conclusions may be very shortly stated. In order that the more temporary, or more rapidly acting means of increasing the produce of meadow land, may have their full effect, the more permanent means of amelioration that may be required—such as draining, marling, liming, and the like—must not be neglected. The application of bones is not recommended for general adoption. They appear to be chiefly adapted to the exhausted pastures of certain localities, and not to be generally applicable to meadow land which is mown for hay. The hay crop is a great exhauster of the mineral constituents of the soil; and these, owing to the high price of salts of potash, cannot, with profit, be fully restored in artificial manures. The return of the mineral constituents is better accomplished by means of farmyard manure, stable dung, night soil, and the like; which, at the same time, bring on to the land a more or less considerable quantity of available nitrogen. The best "*artificial*" manures for grass-land, are, Peruvian guano, which is rich in phosphates as well as nitrogen; and nitrate of soda, and sulphate of ammonia, which are rich in nitrogen, but contain, of course, no phosphates. Peruvian guano, when used alone, may be employed at the rate of from 1½ to 2½ cwts. per acre; nitrate of soda alone, or sulphate (or muriate) of ammonia, at the rate of 1½ to 2 cwts. per acre. The salts of ammonia are, however, relatively too expensive to be employed largely with profit; and both ammonium-salts and nitrate of soda are more advantageously used in combination with guano. A very generally useful top-dressing for the hay crop may be made of 3 parts Peruvian guano, 1 part nitrate of soda, and 1 part sulphate of ammonia. Of this mixture, 2 to 2½ cwts. per acre may be employed. With this applied annually, and the application of 10 or 12 tons per acre of poor rotten dung once every four or five years, a good crop of hay may be taken off every year, without injury to the land. The best time of sowing the "artificial" manures is generally in January; and it should at any rate be seldom postponed beyond February.

Part II.—Produce of Constituents per Acre.

In order that the more directly practical conclusions to be drawn from the experiments might be brought out more prominently, attention was confined in the former section of our Report almost exclusively to the nature of the manures employed, and to the amounts of the gross produce or increase of hay obtained by their use. A few passing remarks only were made upon the variable character of the herbage, according to the description of manure employed. But there are other aspects of the subject than those hitherto considered, which are well worthy the attention of the intelligent farmer.

The permanent meadow land of a farm stands in a somewhat isolated position in regard to the crops under tillage. In the case of the *rotation* crops, the straw of the grain ones, the larger portion of the most important manurial constituents of the green crops, frequently the manure from the consumption of the hay of the meadow land itself, and perhaps that from imported cattle-food also, will, at least once in the course, find their way to the arable land. But the meadow land does not generally come in for a due share of restoration of constituents by the home manures. Hence it happens, that the amount of constituents actually carried from the land, year by year, in the hay crop, has generally a more direct influence on exhaustion, than that harvested in the rotation produce.

It is important to consider then—what amounts of the several constituents are taken from an acre of land in an ordinary crop of hay?—what is the drain of them, which the stores of the soil, or the supplies of other manures, are called upon to meet, when the produce is increased by means of active portable manures?—and further, what is the proportion of the active manurial constituent *nitrogen* supplied in such manures, that is recovered in the increase of crop obtained by its use?

It is also essential to a right appreciation of the action of different manures upon the grass-crop, carefully to ascertain their influence upon the development of the different plants of which the mixed herbage is made up, and at the same time to take into consideration the recognised comparative qualities of the different plants so developed.

Lastly, with a great variation in the proportion of the different plants developed, and in the degree of their maturity at any given time, according to season and the manure employed, it is obvious, that there must be corresponding variation in the percentage composition of the complex produce—*hay*. The influence of the different manures upon the *chemical composition of the hay* constitutes, therefore, another important point of inquiry.

It would perhaps, in some points of view, be more in order to

give the results of the analyses, and with them to consider the *percentage* composition of the hay, before treating of the *acreage* yield of the several constituents, calculated by means of those results; but it will, upon the whole, be more convenient to complete the subject of the *quantity* of produce before commencing upon that of *quality*.

Having, therefore, in Part I., considered the acreage amounts of the *gross produce*, or *hay*, attention will be directed in the present section (Part II.) to the acreage quantities of certain *constituents*, or *classes of constituents*, obtained by the different manures.

Part III. will be devoted to the discussion of one element of quality, namely, that of the description and proportion of the different plants developed.

Lastly, in Part IV., the *percentage composition* of the complex produce—*hay*, will be considered.

The particulars relating to the amount of the several constituents, per acre, contained in the produce by the different manures, are given in a series of Tables, as follow :—

In Table III.—The produce of hay, per acre, calculated in lbs., as the basis of the succeeding Tables.

In Table IV.—The produce of total *dry substance*, per acre, in lbs.

In Table V.—The *mineral matter* (ash), per acre, in lbs.

In Table VI.—The *nitrogen* in the *total produce*, per acre, in lbs.

In Table VII.—The *nitrogen* in the *increase by manure*, per acre, in lbs.

In Table VIII.—The *proportion* of the *nitrogen recovered in increase, for* 100 *parts supplied in manure.*

1. *The Dry Matter per Acre.*

On the amounts of *dry matter*, per acre (Table IV.), a very few observations will suffice. Taking the average of the three years over which the experiments extended, the annual yield of dry matter was, *without manure*, almost exactly a ton per acre. This is slightly under the amount obtained, without manure, in *wheat* (grain and straw together), taking the average of fourteen years of the consecutive growth on the same land; and it is several hundredweights below that obtained in *barley*, without manure, taking the average of six years' consecutive growth on the same land.

By means of *manures*, the yield of dry matter, per acre, in the hay crop, was in several of the experiments considerably more than doubled. The increased produce of dry matter was thus great—indeed the greatest—where no carbonaceous manure whatever was employed. It may be reckoned that the dry substance of the hay would contain about 40 per cent. of carbon. Adopting this estimate, there would be about 900 lbs. of carbon assimilated per acre,

		[illegible]	[illegible]	[illegible]	[illegible] yrs Yearly [illegible]	
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	2515	2856	2472	2614	...
2	Unmanured (duplicate plot)	2351	2592	3360	2768	...
	Mean, or Standard Unmanured...	2433	2724	2916	2691	...
3	2000 lbs. Sawdust	2312	2340	2244	2299	−392
4	200 lbs. each, Sulphate and Muriate Ammonia	4028	3774	3982	3928	1237
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust ...	3953	3710	4166	3943	1252
6	275 lbs. Nitrate of Soda	...	...	2952	...	261
7	550 lbs. Nitrate of Soda	...	...	3564	...	873
	Series 2.—With Direct Mineral Manure.					
8	*"Mixed Mineral Manure"	3429	3666	4082	3726	1035
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	3711	3994	4376	4027	1336
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6363	6422	7172	6652	3961
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6369	6428	6892	6563	3872
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	5412	6050	6752	6071	3380
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6970	6940	7508	7139	4448
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	4236	...	1545
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	5646	...	2955

TABLE IV.—PRODUCE of TOTAL DRY SUBSTANCE per Acre: lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 Years.	Average Annual Increase by Manure.
	SERIES 1.—Without Direct Mineral Manure.					
1	Unmanured	2061¼	2431¾	2124½	2205½	...
2	Unmanured (duplicate plot)	1885¾	2262¾	2872	2340	...
	Mean, or Standard Unmanured	1973½	2347¼	2498¼	2273	...
3	2000 lbs. Sawdust	1866¼	2052¼	1893½	1937¼	−335¾
4	200 lbs. each, Sulphate and Muriate Ammonia	3222¾	3272	3348	3280¾	1007¾
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	3148¼	3251½	3496	3298½	1025¾
6	275 lbs. Nitrate of Soda	...	...	2503¼	...	230¼
7	550 lbs. Nitrate of Soda	...	...	3059¼	...	786¼
	SERIES 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	2751½	3179¾	3493½	3141½	868¼
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	2987	3466¼	3679¼	3377¾	1104¼
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	5024¼	5591½	5889½	5501¾	3228¾
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	4924½	5606½	5778¼	5436½	3163½
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	4286¾	5249½	5562¾	5033	2760
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	5445	5967	6057½	5823	3550
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	3660¼	...	1387¾
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	4811½	...	2538½
	SERIES 3.—With Farmyard Manure.					
	...	3068¼	4552½	3621	3747½	1474½

Plot Nos.	MANURES. (Per Acre, per annum.)	1856.	1857.	1858.	Average of 3 years.	Annual Increase by Manure.
	SERIES 1.—Without Direct Mineral Manure.					
1	Unmanured	157·4	160·7	141·0	153·1	...
2	Unmanured (duplicate plot)	156·1	148·0	186·8	163·7	...
	Mean, or Standard Unmanured	156·8	154·4	163·9	158·4	...
3	2000 lbs. Sawdust	153·0	132·0	113·8	132·9	−25·4
4	200 lbs. each, Sulphate and Muriate Ammonia	259·4	206·8	204·5	223·6	65·2
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	237·5	206·5	222·1	222·0	63·6
6	275 lbs. Nitrate of Soda	...	...	169·1	...	10·7
7	550 lbs. Nitrate of Soda	...	...	191·7	...	33·3
	SERIES 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	237·4	225·8	264·5	242·6	84·2
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	271·3	263·4	283·2	272·6	114·2
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	431·2	403·3	468·5	434·3	275·9
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	447·9	412·4	468·7	443·0	284·6
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	364·1	394·9	451·2	403·4	245·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	457·9	445·5	476·6	460·0	301·6
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	271·1	...	112·7
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	368·1	...	209·7
	SERIES 3.—With Farmyard Manure.					
16	14 Tons Farmyard Manure	293·9	346·7	279·8	306·8	148·4
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	376·5	387·6	358·4	374·2	215·8

Experiments with Different Manures on Permanent Meadow Land.

Table VI.—Produce of Nitrogen per Acre: lbs.

Plot, Nos	MANURES. (Per Acre, per annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 years.	Average Annual Increase by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	42·2	36·8	34·6	37·9	...
2	Unmanured (duplicate plot)	42·1	38·1	45·0	41·7	...
	Mean, or Standard Unmanured	42·2	37·4	39·8	39·8	...
3	2000 lbs. Sawdust	38·6	32·3	31·6	34·2	−5·6
4	200 lbs. each, Sulphate and Muriate Ammonia	63·2	58·5	65·7	62·5	22·7
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	62·8	55·3	65·0	61·0	21·2
6	275 lbs. Nitrate of Soda	...	...	49·6	...	9·8
7	550 lbs. Nitrate of Soda	...	...	60·9	...	21·1
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	57·3	55·4	57·1	56·6	16·8
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	65·7	59·1	60·8	61·9	22·1
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	78·3	75·8	89·6	81·2	41·2
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	80·2	71·3	80·6	77·4	37·6
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·5	80·8	91·1	83·8	44·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	103·8	112·4	128·4	114·9	75·1
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	64·4	...	24·6
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	74·5	...	34·7
	Series 3.—With Farmyard Manure.					

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Increase over the Produce without Manure.				Increase over the Produce by the "Mixed Mineral Manure."			
		1856.	1857.	1858.	Average of 3 Years.	1856.	1857.	1858.	Average of 3 Years.
	Series 1.—Without Direct Mineral Manure.								
4	200 lbs. each, Sulphate and Muriate Ammonia ...	21·1	21·0	25·9	22·7	...	...	...	...
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	20·7	17·8	25·2	21·2	...	...	...	...
6	275 lbs. Nitrate of Soda	...	...	9·8	...	...	...	...	...
7	550 lbs. Nitrate of Soda	...	...	21·1	...	...	...	...	...
	Series 2.—With Direct Mineral Manure.								
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	36·1	38·3	49·8	41·4	21·0	20·4	32·5	24·6
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	38·1	33·9	40·8	37·6	23·0	16·0	23·5	20·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	37·4	43·4	51·3	44·0	22·3	25·5	34·0	27·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	61·7	75·0	88·6	75·1	46·6	57·1	71·2	58·3
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	24·6	...	...	...	7·2	...
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	34·7	...	...	...	17·4	...
	Series 3.—With Farmyard Manure.*								
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia*	26·7	−4·9	18·4	13·4	...	...	...	...

Experiments with Different Manures on Permanent Meadow Land.

Table VIII.—Nitrogen *recovered*, and *not recovered*, in Increase, for 100 supplied in Manure.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Increase taken over the Produce without Manure.					Increase taken over the Produce by the "Mixed Mineral Manure."				
		Percent. of supplied Nitrogen recovered in Increase.				Average Percent. of supplied Nitrogen not recovered in Increase.	Percent. of supplied Nitrogen recovered in Increase.				Average Percent. of supplied Nitrogen not recovered in Increase.
		1856.	1857.	1858.	Average of 3 Years.		1856.	1857.	1858.	Average of 3 Years.	
	Series 1.—Without Direct Mineral Manure.										
4	200 lbs. each, Sulphate and Muriate Ammonia ...	25·7	25·7	31·6	27·7	72·3	...	...	...	...	...
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	23·9	20·6	29·1	24·5	75·5	...	...	...	...	...
6	275 lbs. Nitrate of Soda	...	...	23·8	...	...	...	...	...	...	...
7	550 lbs. Nitrate of Soda	...	...	25·8	...	...	...	...	...	...	...
	Mean	24·8	23·1	...	26·1	73·9	...	...	...	...	...
	Series 2.—With Direct Mineral Manure.										
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	44·0	46·7	60·8	50·5	49·5	25·6	24·9	39·6	30·0	70·0
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	44·0	39·2	47·2	43·5	56·5	26·6	18·5	27·2	24.1	75·9
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	39·5	45·8	54·2	46·5	53·5	23·6	26·9	35·9	28·8	71·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	37·6	45·7	54·0	45·8	54·2	28·4	34·8	43·4	35·5	64·5
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	59·9	...	...	...	...	17·7	...	...
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	42·3	...	...	...	...	21·2	...	...
	Mean	41·3	44·4	54·0	46·6	53·4	26·0	26·3	36·5	29·6	70·4
	Series 3.—With Farmyard Manure.										
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia*	65·2	−12·0	44·9	32·7	67·3	...	...	...	...	...

* The increase in these cases also includes the produce by Unmanured Mineral plots.

acre, in the average annual produce of the unmanured land. Where an enormous amount of organic matter, rich in carbon, was supplied in the form of sawdust, little or no increased assimilation of carbon took place; where a still larger quantity was employed in the form of farm-yard manure (in admixture, therefore, with other active manurial matters), there was a considerable increase in the assimilation of carbon. But, under these circumstances, it is doubtful whether the farm-yard manure itself was the source of the increased amount of carbon fixed, or, at any rate, whether its supply of that substance (in the form of carbonic acid or otherwise), has been at all essential.

Thus, it was by means of mixtures of mineral manures and ammonium-salts, without the direct supply of any carbon, that the greatest increased assimilation of that substance was obtained. For instance, on plots 10 and 13, there was an average of about 1½ ton of increase of dry substance per acre, per annum, by the use of the mixed mineral manure and ammonium-salts. This amount of gross dry increase represents an increased assimilation of carbon, by about 12 cwts. per acre per annum, without the supply of any in the manure. To this enormous extent, therefore, have these *non*-carbon-yielding manures enabled the plants, either by their roots or their leaves, to draw that element, so essential for the maintenance of the respiration, and for the fattening of our animals, from the *atmosphere*:—into which, in the course of the ever-constant revolutions of organic nature, it had been emitted by the combustion or decomposition of the products of former vegetation, or by the respiration of animals fed on former crops:—and into which, it is destined to be returned by the same means, as the resource of future vegetable growth.

It was seen, how unavailing were *mineral manures alone* materially to increase the growth of the *Graminaceous* hay-plants. That is to say, by their supply alone, these plants were not enabled to assimilate an increased amount of either nitrogen or carbon from natural sources. Nor did the supply of one of these elements—*carbon*—enable the plants to draw from natural sources an increased amount of the other element—*nitrogen*. On the other hand, provided there were a sufficiency of the necessary mineral constituents, the supply of the element *nitrogen*, in an available form of combination, increased enormously the assimilation of the atmospheric constituent *carbon*. It may be remarked in passing, that a very similar result is observed when nitrogenous manures are employed for the *Graminaceous crops of our rotations*. Not that no other crops are found to assimilate an increased amount of carbon without its supply in manure, when they have a sufficiency of mineral constituents and available nitrogen within the soil. But compared with others, the

Graminaceous crops appear to be the most strikingly independent of any artificial carbonaceous supply.

2. *The Mineral Matter per Acre.*

The average annual yield per acre of *mineral matter* (Table V.) was, in the *unmanured hay-crop*, 158½ lbs. This, it may be observed, is about 1½ time as much as was contained in the annual *unmanured* produce of either *wheat* or *barley*.

By the use of *ammonium-salts alone*, an average of 223½ lbs., or about 2 cwts. of mineral matter, was annually taken from the land in the hay-crop. This, again, is from 1⅓ to 1½ time as much as was removed in either wheat or barley when similarly manured—that is, by ammonium-salts alone. By the *addition of mineral manures to the same amount of ammonium-salts*, the quantity of mineral matter annually taken off the land in the hay-crop was increased to nearly 4 cwts. per acre. Against this amount, *farm-yard manure* gave an average of only 306¾ lbs. of mineral matter in its annual yield of hay, notwithstanding that it itself contained not only a very large amount of mineral constituents, but of nitrogen also, which is so essential to bring them into play. This comparatively defective action of the constituents of farm-yard manure is, doubtless, owing in great measure to the slow liberation of both the nitrogen and the mineral matter supplied in that form. When *ammonium-salts* were used in *addition to the farm-yard manure*, still only 374¼ lbs. of mineral matter were annually taken from the land; that is to say, still considerably less than when the whole of both the nitrogen and the mineral matter were provided in a more readily available condition.

It is more particularly in *potash*,* that the hay-crop is more exhausting than what might be called a corresponding produce of either wheat or barley. In relation to this point, attention should be called to the fact, that, as practice goes, almost as a matter of course, a notable proportion of the phosphoric acid, and of the magnesia, almost the whole of the silica, and by far the larger proportion of both the lime and the potash, taken from the land in the *wheat* and the *barley* crops, will, at some period of the rotation, be returned to it, in the home-manures to which the straw of these crops has contributed. But, in the case of *meadow-land* associated with land under tillage, it is by no means so probable,

* Independently of the fact that an ordinary hay-crop will contain more mineral matter than the grain and the straw of an ordinary wheat or barley crop, the ash of the *hay* contains about twice as high a percentage of *potash*, as that of the gross produce (grain and straw) of *wheat* or *barley*. But further particulars will be given regarding the *individual mineral constituents* of the *hay*-crop, in Part IV. of our Paper.

that the mineral constituents of the hay will, in anything like a corresponding degree, find their way back from whence they came. It will be obvious, therefore, that, according to current practice, the meadow-land will be much more liable than the arable to become deficient in a due provision of the necessary mineral constituents. These considerations show that both the wheat and the barley-crops may, with comparative impunity, be kept up to a high point of productiveness by means of forcing portable manures, provided only that the crops of the course, as a whole, receive their due share of the home manures. It will, at the same time, be equally obvious, that similar means are not applicable for the production of full crops of hay, unless similar conditions be provided; that is to say, unless the meadow, in its turn, receive a due proportion of the home manures.

Where, however, grass is grown for hay by those holding little or no arable land, it is generally for the supply of a neighbouring town; and in such cases a liberal amount of stable and other town-manures is generally brought upon the land. Under these circumstances, the additional use of the more active portable manures, will not, as a rule, be advantageous.

3. *The Nitrogen per Acre.*

Attention must now be directed to the acreage yield in the hay of the important constituent *nitrogen*. In the experiments under consideration, the annual yield of nitrogen per acre, taking the average result of 3 years, was, *without manure*, 39·8 lbs. (see Table VI.). By the side of this amount it may be mentioned, that the average of 14 consecutive years of *unmanured wheat* gave 30·7 lbs.; and that of 6 consecutive years of *unmanured barley*, 26·5 lbs. of nitrogen.

From these figures it appears, that the hay-crop (so far as the experiment has yet extended) has given from one-third to one-half more nitrogen per acre per annum, without manure, than either wheat or barley. Part of this excess of nitrogen in the hay-crop, though probably not the whole of it, is due to the fact, that the *mixed herbage* of the hay comprised a number of *Leguminous* plants, which contain a higher percentage of nitrogen, and have apparently greater powers of assimilating it from natural sources, than the *Graminaceous* ones. Indeed, where mineral manures alone were employed (Plot 8), under the influence of which the development of *Leguminous* plants was greater than on any of the other plots, there was an average of 56·6 lbs. per acre per annum of nitrogen, without the supply of it in manure, instead of only 39·8 lbs. without manure of any kind. Thus, without the addition of any nitrogenous manure, there was

here an average annual increase of 16·8 lbs. of nitrogen per acre. But this increased yield of nitrogen obtained by the use of mineral manures, it is to be observed, was not due to an increased development of the *Graminaceous*, but to that of the *Leguminous* portion of the herbage. In fact, the annual yield of nitrogen per acre in this case, where the *Leguminous* plants comparatively so much predominated, was nearly double that which has been obtained in the continuously unmanured cereal crops of the arable land.

The next point of consideration in regard to the *nitrogen-statistics* of the *hay-crop*, is one of great interest, both in a practical and scientific point of view; namely, that of the relation of the nitrogen in the *increase*, to that in the *manure* employed to produce it. Tables VII. and VIII. illustrate this part of the subject. Table VII. shows the *actual increase* of nitrogen in the produce (in lbs. per acre), where it was supplied in manure. Table VIII. shows the *proportion* of nitrogen recovered in the increase, for 100 of it supplied in manure. But in both Tables two sets of columns are given. The first of these relates to the increase of nitrogen over that in the *unmanured* produce, and the second to the increase over that in the produce by the "*mixed mineral manure*." The reader has thus the facts put before him in two aspects. It appears to us, however, from a careful consideration of all the circumstances of the experiments, that the only legitimate mode of estimating the amount, or proportion, of nitrogen recovered in the increase of hay, for a given amount of it supplied in the manure, will be to assume the nitrogen of the *unmanured*, and *not* that of the *mineral manured produce*, as the standard or normal yield, upon which to calculate the increase obtained by the action of nitrogenous manure—whether this be used alone, or in addition to mineral manures.

Thus, it must be remembered, that the increase, both of gross produce and of nitrogen, was, when *mineral manures alone* were employed, due to an increased development of *Leguminous* plants. On the other hand, when nitrogenous manures were used, either alone or in combination with mineral manures, the increase was due to the increased development of the *Graminaceous* herbage only. Under these circumstances, it is obvious, that the whole increase by the combined action of both nitrogenous and mineral manures (it being almost entirely graminaceous), must be supposed to be due, *so far as the resources of nitrogen are concerned*, to that artificially supplied in the manure. That is to say, bearing in mind the difference in the *description* and *composition* of the herbage grown by mineral manures alone, and by mineral manures in admixture with nitrogenous ones, the influence of the

addition of the nitrogen is not represented simply by the difference between the prominently *Leguminous* produce by mineral manures alone, and the almost exclusively *Graminaceous* produce, when nitrogenous as well as mineral manures are employed. It will be obviously much nearer the truth to assume, that the artificially supplied nitrogen—whether employed alone or in conjunction with mineral manures—was engaged in the production of *at least* the whole amount of increase *above* the produce *without manure.*

In fact, it is not impossible that, in even this mode of estimate, the degree in which the artificially-supplied nitrogen has been involved in the amount and composition of the produce, is somewhat understated. For, even the *unmanured* produce contained more of the highly-nitrogenized *Leguminous* herbage, than did that grown by either ammonium-salts alone, or by ammonium-salts in conjunction with mineral manure. Hence, it might be concluded, that the point beyond which the artificially-supplied nitrogen became involved in the production of *Graminaceous* increase, would be even *below* that represented by the acreage yield of nitrogen *without manure.* For, that amount depended materially upon the quantity of the highly *Leguminous* herbage in the unmanured produce, which was at once diminished on the addition of nitrogenous manures.

For the above reasons, then, it is assumed that, at least the whole of the nitrogen in the produce by nitrogenous manures *beyond that yielded on the unmanured plot* may be calculated as due, in a certain sense, to that which was artificially supplied—whether or not the nitrogen was so supplied alone, or was aided in its action by conjunction with mineral manures. At the same time, it is freely granted, that the legitimacy of any estimates regarding the proportion of the nitrogen supplied by manure which is involved in the increase obtained by its use, must rest entirely on that of the assumption made as to the amount of the whole nitrogen of the produce, which is to be attributed to natural sources. It is not, indeed, possible, to obtain actual proof, that produce grown by nitrogenous manures has really assimilated *neither more nor less* of nitrogen from other sources, than that grown without them. It might be supposed that, with a ready supply of available nitrogen within a limited range of the soil, the plants would draw less upon the natural or unaided resources. On the other hand, it might be assumed that, with the increased vigour of growth due to nitrogenous manure, the feeders of the plant would be so extended, both above and under ground, as to increase its command over the natural resources of available nitrogen. It is obvious, therefore, that the best estimate to which our judgment can lead, cannot, after all, be looked upon

as representing with certainty, the exact proportions in which the nitrogen of the manured produce has, in point of fact, been obtained from the natural and the artificial sources respectively. These observations will sufficiently indicate the degree of reservation with which the figures in the Tables, and the arguments founded upon them, should be accepted.

In regard to the figures in Table VII., which show in lbs. the *actual increase of nitrogen per acre by its use in manure*, it should be explained, that, where 400 lbs. of ammonium-salts, or 550 lbs. of nitrate of soda, were employed per acre, it is estimated that 82 lbs. of nitrogen were thereby supplied. The 275 lbs. of nitrate of soda is, of course, assumed to supply half, and the 800 lbs. of ammonium-salts double that amount. The 2000 lbs. of sawdust, according to direct analysis, would contain only $4\frac{1}{2}$ lbs. of nitrogen. It is, then, to these amounts of nitrogen *supplied*, that those recorded in the Table as *increase*, are to be respectively referred.

But it is in Table VIII., where the *increase* of nitrogen in the produce is, for each experiment, calculated in relation to 100 parts of it supplied in manure, that the *proportion* of the nitrogen assumed to be recovered, to that supplied, is brought to view the most clearly.

Where ammonium-salts were used alone (see upper Division of Table VIII.), there was, taking the average of the three years, only 27·7 *per cent.* of the supplied nitrogen recovered in the increase. And where the ammonium-salts and sawdust were used, there was somewhat less still recovered, namely, 24·5 per cent.

The nitrate of soda, which was employed in one season only, and then sown somewhat disadvantageously late, when it was used alone, returned in the increase of produce nearly the same proportion of its nitrogen as the ammonium-salts (as just quoted)—namely, 23·8 per cent. when the smaller amount, and 25·8 when the larger amount of the salt was used. But in reference to this result, it should be mentioned, that the *percentage* of nitrogen in the hay grown by the nitrate, was notably higher than in that grown by the ammonium-salts in the same season; in fact, the proportion of nitrogen in the former was somewhat abnormally high.

The result was, then, that where either ammonium-salts or nitrate of soda were employed without the aid of the mineral manure, there was only about *one-fourth* of the supplied nitrogen recovered in the immediate increase of the hay-crop.

In connexion with the result just stated attention may be called to the fact, that if, where both mineral and nitrogenous manures are employed (see lower Division of Table VIII.), the

increase of nitrogen in the produce by the use of it in manure is supposed to be represented by *so much only* as was over and above that yielded by the *mineral manures alone*, there would then appear to be only about the same proportion of the supplied nitrogen recovered as when the nitrogenous manures were used alone, and the increase of nitrogen then calculated over that in the *unmanured* crop. Thus, taking, as supposed, the yield of nitrogen by the *mineral manures alone* as the basis of the calculation, the increase obtained by the super-addition of the 400 lbs. of ammonium-salts will have returned only 30 per cent.; that by the 400 lbs. of ammonium-salts, and 2000 lbs. of sawdust, only 24·1 per cent.; that by the 400 lbs. of ammonium-salts and 2000 lbs. of cut wheat-straw, only 28·8 per cent.; and that by the 800 lbs. of ammonium-salts, 35·5 per cent., of the supplied nitrogen. In regard to the fact, that there appears to be a larger proportion of the supplied nitrogen recovered (35·5 per cent.) when the extravagant amount of 800 lbs. of ammonium-salts per acre was employed, it may be stated that the result is due to an extremely *high percentage* of nitrogen in the produce, and not to a favourable proportion of increase. The larger return of the supplied nitrogen is, therefore, though an apparent, yet only a questionable advantage. Adopting the same mode of calculation as above, the addition of nitrate of soda to the mineral manures gave a less favourable result than that of ammonium-salts. When 41 lbs. of nitrogen were employed in the form of nitrate, there were only 17·7 per cent.; and when 82 lbs. of nitrogen were so provided, there were only 21·2 per cent. of the supplied nitrogen recovered in the increase.

But, reckoning, as has been shown it would be more proper to do, that the whole of the nitrogen obtained by the conjoint action of the mineral and nitrogenous manures *beyond that yielded without manure*, has probably been due to that artificially supplied, the proportional return in the immediate increase then appears to be much greater. On this mode of estimation, the 400 lbs. of ammonium-salts (with mineral manure) have returned in the increase 50·5 per cent.; the 400 lbs. of ammonium-salts and 2000 lbs. of sawdust (with mineral manure) 43·5 per cent.; the 400 lbs. of ammonium-salts and 2000 lbs. of cut wheat-straw (with mineral manure) 46·5 per cent.; the 800 lbs. of ammonium-salts (with mineral manure) 45·8 per cent.; the 275 lbs. of nitrate of soda (with mineral manure) 59·9 per cent.; and the 550 lbs. of nitrate of soda (with mineral manure) 42·3 per cent., of the nitrogen supplied in the manure.

Taking the average of the results just quoted, there were about 48 per cent. of the supplied nitrogen recovered in the immediate increase of the hay-crop, when the nitrogenous manure was asso-

ciated with a liberal provision of the necessary mineral constituents. Such at any rate is the result, on the assumption that as much of the nitrogen of the produce as was *in excess of that obtained without manure*, is to be attributed to that which was *artificially supplied*. When, however, the same nitrogenous manures were employed without the aid of mineral manures, only about half as much of the supplied nitrogen appeared to be recovered in the immediate increase. There was, moreover, little more than half as much of the supplied nitrogen estimated as recovered, if, when mineral and nitrogenous manures were used together, the yield of nitrogen by the *mineral manures alone*, instead of that *without manure*, were assumed to represent the amount obtained from natural sources. But, even though the *larger* amount may more nearly represent the actual proportion of the supplied nitrogen which was recovered in the increase when mineral manures were also used, it will be, at the same time, obvious that, in a certain *practical* sense, the only *gain* of nitrogen in produce by the addition of it to mineral manures, is that amount beyond what would have been obtained by the *mineral manures alone*.

On other occasions it has been shown, that, in the growth of full crops of either *wheat* or *barley* by the direct application of nitrogenous manures, little more than 40 per cent. of the supplied nitrogen could be estimated as recovered in the immediate increase obtained. It might perhaps be anticipated, that the result would be different in the case of the *hay-crop*. Not only are but few of the plants composing it fully ripe at the time of being cut, but their roots have a much more complete possession of the whole area of the superficial layers of soil. So far as the experiments have yet extended, the *hay-crop* does not appear to return in its immediate increase, a larger proportion of the supplied nitrogen compared with *wheat* or *barley*, than might perhaps with reason be attributed to the more extended distribution of the feeders of the crop on a given area of land.

It appears, then, from the evidence as yet at command, that in the case of the *grass-crop*, as in that of the *ripened cereal grains*, a considerable proportion of the expensive constituent—*nitrogen*—which may be supplied in manure, has to be reckoned as *unrecovered* in either the immediate or the closely-succeeding increase of crop.

The possible explanations of this loss of nitrogen—real or apparent as the case may be—are numerous; but they are more or less within the reach of careful and extended experimental inquiry. It may be supposed—that a portion of the unrecovered amount of nitrogen is, in some form, drained away and lost?—that the supplied nitrogenous compound is transformed in the soil,

and nitrogen in some form evaporated?—that a portion remains in the soil in some fixed and unavailable state of combination?—that ammonia, or some other compound of nitrogen, or free nitrogen itself, is given off during the growth of the plant?—or, it may be, that the range of distribution of the supplied nitrogen, and its state of combination within the soil, are alone sufficient obstacles to its being taken up in larger proportion by the immediate crop? Should the last supposition afford a sufficient explanation of the facts observed, the assumed loss would be one but in appearance merely. The farmer might then still hope to reap the whole benefit of his costly nitrogenous manures, in the course of time, in succeeding crops. Be this as it may, the facts that have been recorded afford additional confirmation of the opinion so frequently insisted upon, that, in the case of the *Graminaceous* plants which we cultivate, a full crop is obtained only when there is a liberal provision of *available nitrogen within the soil*; and, further, that when this provision is made by means of direct nitrogenous manures, a large proportion of the so-supplied nitrogen will remain *unrecovered in the increase of crop*, at least for a considerable period of time.

The main facts elicited on a consideration of the *acreage yield* in the *hay-crop*, of some of its important *constituents*, or *classes of constituents*, according to the condition of manuring, may be summed up as follows:—

1. The average annual produce of *Total Dry Substance*, in the *unmanured meadow-hay-crop*, was about 1 ton per acre, which would contain about 900 lbs. of *carbon*. These amounts are somewhat less than were annually obtained *without manure* in either *wheat* or *barley*.

2. *Purely carbonaceous manures* did not appear to increase the assimilation by the *Graminaceous* herbage of either *carbon* or *nitrogen*.

3. *Purely mineral manures* induced little or no increased assimilation of either *carbon* or *nitrogen* by the *Graminaceous*, but a considerable amount by the *Leguminous* herbage.

4. *Specially nitrogenous manures*, such as ammonium-salts, even when used alone, notably increased the assimilation of *carbon* and *nitrogen* by the *Graminaceous*, but not by the *Leguminous* herbage.

5. By means of manures supplying *both mineral constituents and nitrogen*, but no carbon, there was an annual increase of *Graminaceous* produce, equal to about 1½ ton of *dry substance* per acre, which would contain about 12 cwts. of *carbon*.

6. The annual yield of *mineral constituents* in the *unmanured*

hay-crop was nearly 1½ cwt. This amount is about one-and-a-half time as much as was contained in either *wheat* or *barley* when *unmanured.*

7. By means of *mineral manure alone*, or *ammonium-salts alone*, the annual yield of *mineral matter* in the hay-crop was raised to about 2 cwts. per acre; and by *mineral and nitrogenous manure combined*, to about 4 cwts. per acre.

8. It is particularly in *potash*, that the *hay-crop* is more exhaustive of soil-constituents, than either *wheat* or *barley.*

9. Owing to the comparatively large amount of *mineral constituents* taken from the land in the *hay-crop*—to the less regular return of them by the *home manures*—and to the less exposure of the soil in the case of *meadow-land*—more special attention is required to prevent *its* practical exhaustion of soil-constituents, than in the case of *arable-rotation-land.*

10. The annual yield of *nitrogen* per acre was, in the *unmanured hay-crop*, nearly 40 lbs. This is from one-third to one-half *more* than was annually obtained in *unmanured wheat* or *barley.*

11. The hay grown by *mineral manures alone*, yielded considerably *more nitrogen per acre* than that grown *without manure.* The increased amount was due to an increased growth of the *Leguminous*, and not of the *Graminaceous* herbage.

12. *Nitrogenous manures alone* (ammonium-salts and nitrate of soda) gave an *increase of nitrogen in the produce* equal to only about *one-fourth of that supplied in the manure.*

13. *Mineral and nitrogenous manures combined* gave an *increased produce of nitrogen* equal to from 45 to 50 per cent. of the *nitrogen supplied in the manure. Wheat* and *barley*, under similar circumstances, gave an increased produce of nitrogen equal to rather more than 40 per cent. of that supplied in the manure. The rather more favourable result with the *hay-crop* is not more than is probably attributable to the more complete distribution of the under-ground feeders of the crop.

14. In the case of the *meadow-grasses*, as in that of the *Graminaceous plants grown in rotation*, the growth was much increased by *direct nitrogenous manures;* and, in both cases, from 50 to 60 per cent. of the *supplied nitrogen* remained *unrecovered* in either the immediate, or the closely-succeeding increase of crop.

Part III.—Description of Plants developed by different Manures.

Perhaps the most remarkable and interesting of the effects of the different descriptions of manure, upon the complex herbage of which the experimental meadow was composed, was the very

varying degree in which they respectively developed the different kinds of plants.

Allusion has already frequently been made, in a cursory way, to the greater development of the *Leguminous* herbage by purely *mineral manures*, and to that of the *Graminaceous* plants, or natural grasses commonly so-called, by characteristically *nitrogenous manures*. In fact, the plots had each so distinctive a character in regard to the prevalence of different plants, that the experimental ground looked almost as much as if it were devoted to trials with different seeds as with different manures. So striking and characteristic, indeed, were the effects produced in this respect, that, in 1857 and 1858, the subject was thought of sufficient interest to induce us to request the examination of the plots by Professor Henfrey, to which he kindly assented.

An endeavour was also made in the second year, 1857, to separate, and determine, the proportion of the different plants in carefully averaged and weighed samples, taken from the several plots as soon as the grass was cut. Taking advantage of the experience gained in this first trial, the separations have been carried out more carefully in the case of the produce on some of the most important plots in the third season, 1858. The results of these separations are recorded in detail in Table IX., pp. 46-7, and in a summary form in Table X., p. 48; and it is the consideration of those results that will constitute the subject of this Third Part of our Report.

The mode of proceeding in making the separations and estimations may be shortly explained. As soon as the grass on a plot was cut down, samples were taken from many parts of it. These were carefully intermixed in such manner as to shake out as little seed as possible; and then, from the whole, a certain quantity was weighed out to be further operated upon. Characteristic specimens of each of the plants *in flower or seed*, or in other conditions in which they could be recognised, were then selected as types; and a number of boys were set to pick from the weighed sample, all they could find to correspond with these types. The remainder consisted chiefly of *detached foliage, and undeveloped stems*, which was then separated into four or five different lots, according to types selected to the best of our judgment. Each weighed sample was thus divided into from fifteen to twenty different descriptions of herbage. The weight of each of the selected portions was afterwards taken—all in an equal condition of dryness. The weights so obtained, of the respective grasses, or other plants, or parts of plants, in the original weighed sample from the plot, were then calculated into their percentage relation to the collective weight of the whole of the separated portions in their partially dried state. It is the results

so obtained that are recorded in the Tables. It should be mentioned, that we are indebted to Dr. Evan Pugh, of Pennsylvania, for the superintendence of the Botanical part of the inquiry.

It will be obvious, that absolute exactness in the determination of the proportions in which the different plants really occurred on the respective plots, would be extremely difficult to attain. If the bulk of the sample taken were so large as to exclude all possible doubt of its being a fair average of the whole produce, the labour of the separations would be so great as to be almost impracticable. There is, however, no doubt that the Tables do, in the main, very closely represent the facts. They do so, at any rate, quite sufficiently to bring very strikingly to view the most characteristic and important distinctions that were observed to be developed.

In the respective columns of the Table of detail (IX.) are given :—

1st. The Botanical names of the plants.
2nd. The Common or English names.
3rd. The *percentage proportions* of each plant, &c., on some of the most important of the experimental plots.
4th. Notes taken on a comparative examination of the specimens.

The plots selected for the Botanical analysis of their produce were :—

Plot 1. Unmanured.
Plot 4. With ammonium-salts alone.
Plot 8. With the "mixed mineral manure" * alone.
Plot 10. With the "mixed mineral manure," and ammonium-salts.
Plot 13. With the "mixed mineral manure" and the double quantity of ammonium-salts.
Plot 16. With farmyard manure.
Plot 17. With farmyard manure and ammonium-salts.

The separated plants are classified into :—

1st. Graminaceous herbage (Grasses commonly so called), in culm, bearing flower or seed.
2nd. Graminaceous herbage, detached leaf and undeveloped stem.
3rd. Leguminous herbage.
4th. Miscellaneous herbage, chiefly weeds.

Within each of these classes, the plants are enumerated in the Table, *in the order in which they respectively occurred in the largest*

* For full description of the "*Mixed Mineral Manure*," see Part I. of this Paper.

roportion on the unmanured plot. The comparison of the figures n the column relating to any particular *manured* plot, with those elating to the *unmanured*, thus shows at once, the deviation from he standard result which is induced by the manure in question, oth as regards the *order* as to quantity, and the *actual numerical roportion*, in which the different descriptions of herbage were found to be developed.

In addition to the above explanation, it will be an useful further preliminary to the discussion of the effects of the different manures, to make a few remarks on the general character of the herbage of the experimental meadow.

In the third season (1858), to which our Table of separations refers, there was no *Dactylis glomerata* (Rough Cock's-foot), no *Poa pratensis* (Smoothed-stalked Meadow-grass), no *Bromus mollis* (Soft Brome-grass), and no *Avena pratensis* (Meadow Oat-grass), detected in the produce of the *unmanured* plot. The Rough Cock's-foot and Smooth-stalked Meadow-grass occurred, however, on some of the manured plots; and each in large proportion under certain conditions of manuring. But the Soft Brome-grass, and Meadow Oat-grass, occurred in very few cases at all, and then in very small quantity. There was, too, a striking absence, on all the plots, of several esteemed permanent meadow-grasses. Thus *Alopecurus pratensis* (Meadow Foxtail), *Festuca pratense* (Meadow Fescue), *F. duriuscula* (Hard Fescue), *Phleum pratense* (Meadow Cat's-tail), and *Poa trivialis* (Rough-stalked Meadow-grass), were not found in our list at all in the third season, 1858. The Meadow Fox-tail, the Meadow Cat's-tail, and a Fescue-grass were, however, each observed on one or more of the plots in 1857.

Attention may now be directed to the comparative development of each of the plants according to the manure employed, taking each *seriatim*, in the order in which it predominated on the unmanured land. A short statement of the reputed characters of each, as to its adaptation to local conditions, and as to its recognised agricultural value, will, at the same time, be given.* The comparative development of the different *Graminaceous* plants will be first considered. The records relating to these are given in the two upper Divisions of the Table (IX.); those in the first refer to the plants *in culm*, and those in the second to the *leafy and indeterminate Graminaceous produce.*

* See on these points, Lawson's 'Synopsis of Vegetable Products,' &c.; Bravender's 'Prize Report,' Journal of the Royal Agricultural Society of England, vol. v., part ii.; Professor Buckman's Papers, Journal of the Royal Agricultural Society of England, vol. xv., p. 462, vol. xvii., p. 162, and vol. xvii., p. 513; Donaldson 'On Manures and Grasses;' and Morton's 'Cyclopædia of Agriculture.'

EXPERIMENTS with DIFFERENT

TABLE IX.—Showing the Description and Proportions of the Differe

DESCRIPTION OF THE HERBAGE.		PERCENTAGE AMOUNTS			
			Artifical Manur		
Botanical Names.	Common Names.	Unmanured. (Plot 1.)	Ammonium-salts alone. (Plot 4.)	"Mixed Mineral Manure." (Plot 8.)	"Mix Miner Manur and A monia salts (Plot
1.—Graminaceous Herba					
Lolium perenne	Common rye-grass	16·77	14·73	23·39	32·23
Holcus lanatus	Woolly soft-grass, or Yorkshire Fog	14·02	14·43	6·94	27·64
Arrhenatherum avenaceum	Fibrous-rooted, tall oat-like grass	6·04	3·27	9·07	4·94
Anthoxanthum odoratum	Sweet-scented vernal grass	5·43	0·41	1·01	0·00
Agrostis vulgaris	Common or creeping-rooted bent-grass, also black switch, &c.	4·82	0·97	0·03	1·48
Briza media	Common quaking-grass	2·07	0·41	1·91	—
Cynosurus cristatus	Crested dog's-tail grass	1·10	0·05	0·20	—
Dactylis glomerata	Rough cock's-foot	...	1·64	—	1·28
Poa pratensis*	Smooth-stalked meadow grass*	...	...	—	—
Bromus mollis	Soft or downy brome-grass	...	...	—	—
Avena pratensis	Meadow oat-grass	...	...	0·24	—
	Total	50·25	35·91	42·18	72·66
2.—Graminaceous Herbage;					
Leafy produce—from woolly soft-grass		3·41	12·28	3·46	4·06
Coarse leaf, &c.—some bent-grass; probably also cock's-foot, soft brome-grass, and others		8·78	11·46	1·79	6·64
Middling leaf—chiefly bent-grass; some meadow oat-grass, &c.		3·41	8·18	14·33	4·43
Fine leaf, &c.—unknown; possibly some Festuca bromoides, or barren fescue grass		7·81	16·37	5·62	2·53
Dead leaves and stems		2·44	4·91	2·24	1·01
	Total	25·85	53·20	29·64	24·71
3.—L					
Lathyrus pratensis	Yellow or meadow vetchling	2·07	2·20	4·53	—
Lotus corniculatus	Common bird's-foot trefoil	1·83	...	0·45	—
Trifolium pratense perenne†	Perennial red clover†	1·22	...	17·91	—
	Total	5·12	2·20	22·89	—
4.—Miscellaneous					
Plantago lanceolata	Rib-grass or plantain	10·79	0·41	—	0·00
Carum carui	Common caraway	1·71	...	0·76	0·28
Achillæa millefolium	Common milfoil or yarrow	1·24	3·56	0·48	0·28
Rumex acetosa	Sheep's sorrel or dock	0·67	1·02	0·23	0·84
Silene	Catchfly	0·61	...	...	—
Ranunculus‡	Crow-foot	0·49	1·13	...	...
Luzula campestris	Field wood-rush	0·12	...	...	...
Veronica chamædrys	Germander speedwell	...	...	0·23	...
Galium verum	Common yellow-flowered bed-straw, or cheese rennet	...	...	...	0·32
	Total	15·73	6·14	1·71	1·45

* With some Agrostis. † With some T

m PERMANENT MEADOW LAND.

Herbage developed, according to the Manure employed. 3rd Season, 1858.

PLANT, &c.		NOTES.		
Farm-yard Manure.				
Alone. (Plot 16.)	With Ammoniumsalts. (Plot 17.)	Order of Luxuriance.	Order of Ripeness.	General Condition.
Bearing Flower or Seed.				
2·00	14·93	Plots 15, 16, 17, 8, 13; 1 and 4	Plots 8 and 4; 1; 13 and 16, nearly ripe; 17, unevenly ripe; 10, rather green	On all plots more or less shedded, remaining seeds not ripe.
1·75	19·87	Plots 10, 13, 17, 16 and 4; 1; and 8	Plots 8; 16 and 17, nearly ripe; 4 and 1, greenish; 10 and 13, green	Rather green, little difference, 10 and 13 affected by bulk and laying.
1·33	17·16	Plots 17, 16, 10, 1, 8 and 4; and 13	Plots 4, ripe; 1 and 8, pretty ripe; 17, part dead ripe; 13, nearly ripe; 10 and 16, part ripe	On every plot two distinct grades of ripeness: some dead ripe, some green.
0·34	0·66	Plots 1, 8, 4, and 10, 16 and 17	Plots 17, dead ripe; 8, 4, and 10, ripe; 1, mostly ripe; 16, nearly ripe	All dead ripe, chiefly shedded.
...	1·25	Plots 1, 10, and 13; 17, 4, and 8	Plots 10, dead ripe; 8, and 4, ripe; 13, unevenly ripe; 17, greenish; 1, green	
...	...	Plots 1, 8, and 4	Plots 8; 1 and 4, ripe	All nearly ripe.
0·45	0·26	Plots 1 and 16; 17, 8, and 4 and 13	Plots 8, 4 and 13, ripe; 16, tolerably ripe; 17, middling; 1, greenish	All in full head.
...	...	Plots 13, 10, and 4	Plot 4; 10, nearly ripe; 13, greenish	Seeds not quite ripe.
1·69	10·10	Plots 16 and 17	Plots 16; 17	Generally dead ripe.
...	...	. .	Ripe	Ripe.
...	0·40	. .	Plots 17, dead ripe; 8 and 13, ripe	Dead ripe and mostly shedded.
6·78	64·62			
Leaves and indeterminate Stems.				
7·24	5·55			
3·58	1·32			
4·03	...			
6·48	4·22			
3·58	3·96			
17·91	15·05			
Herbage.				
2·02	1·32	Plots 8, 1, 4 and 16; and 17	Plots 1, little seeded; 4, no ripe seed; 16, in flower; 8 and 17, green and in flower	All in flower.
...	...	Plots 1 and 8	Plots 8, in flower; 1, chiefly in flower, green	In flower, plants green.
1·68	0·46	Plots 8, 16, 1, and 17	Plots 1; 17, scarcely ripe; 8, in full head; 16, some flowers, greenish	Green; chiefly in bloom; turning.
3·70	1·78			
Chiefly Weeds.				
1·96	8·25	Plots 17, 1, 16, 4, and 10	Plots 4, pretty ripe; 10 and 17, nearly ripe; 16; 1, full head, not ripe	All in head, but seeds not ripe.
1·62	1·72	Plots 16 and 17, 1, 8 and 10	Plots 17; 1, seed shedding; 8, 10, and 16, ripe	All ripe.
0·22	1·78	Plots 4, 17, 1, 8, 10 and 13, and 16	Plots 13; 1 and 16, not in flower; 8 and 10, greenish; 4 and 17, green	None in flower; all green.
1·12	3·10	Plots 17, 10, 13 and 16, 1 and 4, and 8	Plots 1 and 8; 16, nearly ripe; 4 and 17, some seeded; 10 and 13, green	Some in bloom; some with ripe seeds.
...	...	. .	Ripe	Ripe.
2·02	1·58	Plots 16, 17, 4, and 1	Plots 17, seed ripe; 16, in seed; 1, in seed, leaves green; 4, flowers and seed	Stems bearing ripe seed, but having green radical leaves.
...	...	. .	Ripe: seeded	Ripe.
0·11	...	Plots 8 and 16	Plots 8 and 16, in flower	In flower.
...	...	. .	. .	Not yet in flower.
7·05	16·43			

: Various species.

TABLE X.—Summary of the facts given in more detail in Table IX.

	PERCENTAGE AMOUNTS OF EACH PLANT, &c.						
		Artificial Manures.				Farm-yard Manure.	
	Unmanured.	Ammonium-salts alone.	"Mixed Mineral Manure."	"Mixed Mineral Manure" and Ammonium-salts.	"Mixed Mineral Manure" and double quantity Ammonium-salts.	Alone.	With Ammonium-salts.
	(Plot 1.)	(Plot 4.)	(Plot 8.)	(Plot 10.)	(Plot 13.)	(Plot 16.)	(Plot 17.)
Total Grasses in flower or seed	50·25	35·91	42·18	72·66	65·08	69·76	64·63
Total Grasses in condition of detached leaves and indeterminate stems .	25·85	53·20	29·64	24·72	32·27	17·91	15·95
Total Graminaceous herbage	76·10	89·11	71·82	97·38	97·35	87·67	79·67
Total Leguminous herbage .	5·12	2·20	22·89	—	—	2·76	1·79
Total Miscellaneous herbage (chiefly weeds) . .	15·73	6·14	1·71	1·85	1·67	7·05	16·43
	96·95	97·45	96·42	99·23	99·02	97·42	97·88
Shedded seeds, &c., &c. .	3·05	2·55	3·58	0·77	0·98	1·58	2·12
Total . . .	100·00	100·00	100·00	100·00	100·00	100·00	100·00

I. GRAMINACEOUS HERBAGE.

1.—*Lolium perenne*—*Common Rye-Grass.*

This grass is reputed to be suitable to a great variety of soils, but to vary very much in character according to external conditions. It is easily propagated, is luxuriant and succulent, and yields an earlier feed than most other grasses. It is relished by stock, yields good hay, and is, in fact, one of the most generally useful of grasses. It flowers in June and July.

The grass having these reputed characters stands at the head of the list as to quantity *in culm*, not only on the unmanured plot, but on several of the others also. What proportion of the *detached leaf and undeveloped stem*, on the different plots, belonged to this grass, we were not able to determine. In the condition of flowering or seeding stem, the produce without manure contained 16·8 per cent. of it, that by purely mineral manures 23·4 per cent., that by ammonium-salts alone 14·7 per cent., that by the "mixed mineral manure" and 400 lbs. of ammonium-salts 32·2 per cent., and that by the "mixed mineral manure" and 800 lbs. of ammonium-salts only 12·1 per cent. of it. Against these proportions of flowering and seeding Lolium, on the unmanured and artificially manured plots, the produce by the farm-yard manure contained 29 per cent. of it, and that by the farm-yard manure and ammonium-salts only 14·9 per cent.

The general result in regard to the amount of Rye-grass in

owering and seeding stem, according to manure, is as follows:— he proportion of it in the total produce was considerably in-reased by the "mixed mineral manures" alone, by the "mixed ıineral manures" and the smaller amount of ammonium-salts, nd by the farm-yard manure alone. On the other hand, its propor-ion was diminished whenever the ammonium-salts were used in elative excess; that is, when the ammonium-salts were used lone, when they were used (with the mineral manures) in double uantity, and when they were employed in addition to the farm-ard manure. When the ammonium-salts were used *alone*, the ıroportion of *Graminaceous leaf and undeveloped stem* was very ıigh; when those salts were used in *excessive* amount with the ıineral manures, the proportion of *two other grasses* (the Woolly oft-grass and the Rough Cock's-foot) predominated over that of he Rye-grass; and when the ammonium-salts were used in ad-lition to farm-yard manure, *three other plants* (Woolly soft-grass, Tall Oat-like grass, and Smooth-stalked Meadow-grass) seemed o gain upon the Rye-grass in degree of luxuriance.

Before passing to the next plant on the list, a few remarks nay be appropriately made, which have a bearing not only on he interpretation of the results just given, but on that of those vhich have to follow. It must not be supposed, that figures vhich represent the proportion of *flowering and seeding stem* of ı certain plant at one given period of the season, are at the same ime accurate indications of the relative development of the *total ılant* under the conditions in question. It must be borne in nind, that the numerous plants which constitute the complex ıerbage of our meadows, have each their natural period of flower-ng and seeding. This period will, however, be accelerated or ıostponed, as the case may be, by the external circumstances of ıoil, season, manure, and the association with other plants. Jeneral observation shows, that *nitrogenous* manures have a ıharacteristic tendency to increase the development of *leaves and ıhoots* in our Graminaceous herbage. *Mineral* manures, on the ıther hand, induce much more the *seeding tendency*. With full ıupplies of mineral manures, therefore, we should expect (other ıonditions being favourable) that there would be a larger pro-ıortion of the growing plant in culm, at a given period, than vhen ammonia was supplied in relative excess. The general esult was, indeed, that the proportion of the total Graminaceous ılants which was *in culm*, was the greater where the mineral ıupplies predominated, and the proportion in leaf and unde-eloped stem the greater when ammonium-salts predominated. Hence, the effect of a manure on the development of the *total ılant*, cannot be determined unconditionally by the proportion ound in flowering and seeding stem.

The evidence is, nevertheless, sufficiently clear, that the bulky, luxuriant, and generally useful *Rye-grass*, was considerably developed by high artificial manuring, when this supplied a sufficiency of mineral constituents, and a pretty full, but not excessive, amount of nitrogen. But when ammonium-salts were used in addition to farm-yard manure, the proportion of the Rye-grass appeared to be diminished. It will be afterwards seen, that this result was due to the fact, that two other grasses (Tall Oat-like grass, and Smooth-stalked Meadow-grass), which occurred either in comparatively small proportion, or not at all, on the other plots, were very considerably developed by the farm-yard manure.

2.—*Holcus lanatus—Woolly Soft-Grass, or Yorkshire Fog.*

This grass is said to be natural to damp and peaty soils; to give a considerable amount of after-math, but not to be liked by cattle either when green or in hay, being too soft, spongy, and insipid. In fact, some consider it as almost a weed. It is further said, to usurp the land in sandy soils, not to be reduced by cultivation, and to have the tendency to banish the artificial grasses. It flowers in July.

Such are the characters of the grass which was found second in amount among those in *culm*, on the unmanured land. It occurred, however, in larger proportion still on some of the manured plots. A considerable proportion of the *leafy* produce was also referred to this plant. The Woolly soft-grass, in the condition of flowering and seeding stem, constituted 14 per cent. of the produce without manure, 6·9 per cent. of that by mineral manures alone, 14·4 per cent. of that by ammonium-salts alone, 32·6 per cent. of that by the mineral manures and 400 lbs. per acre of ammonium-salts, and 26·4 per cent. of that by the mineral manures and the 800 lbs. of ammonium-salts. Lastly, in the produce by farm-yard manure alone, the proportion was only 10·7 per cent., and in that by farm-yard manure and ammonium-salts 19·9 per cent.

The general result was, that the proportion of the Woolly soft-grass was very much increased by nitrogenous manures. The effect was the more apparent when the leafy portion of the produce attributed to this plant was taken into the calculation. In fact, it is those artificial manures which developed the largest proportions of *total Graminaceous herbage*, that yielded the largest amounts of this grass. It amounted, culm and leaf together, to more than a quarter of the total produce when ammonium-salts were used alone, to nearly 40 per cent. of it when the mineral manures and the 400 lbs. of ammonium-salts were employed, and to more than 40 per cent. of the total produce when

the mineral manures and the 800 lbs. of ammonium-salts were used. The proportion of the whole which was in the condition of leaf and undeveloped stem, was much the greatest where the ammonium-salts were in relative excess; that is to say, when those salts were either used *alone*, or in the *double quantity with the mineral manures*. Where farm-yard manure was employed the Woolly soft-grass, like the Rye-grass, as mentioned above, appeared to be somewhat displaced in its proportion by the predominance of two other grasses (Oat-like grass, and Smooth-stalked meadow grass), to which further reference will be made presently. Still, by the addition of ammonium-salts even to farm-yard manure, the proportion of the Woolly soft-grass was considerably increased.

This Woolly soft-grass, and the Rye-grass together, constituted about one-third of the total produce without manure; they together made up more than two-thirds of that by the mineral manures and the smaller amount of ammonium-salts; and more than half of that by the mineral manures and double amount of ammonium-salts.* Upon the whole, it appears that, although the Rye-grass is much increased by nitrogenous manures, the Woolly soft-grass is even more characteristically so; the latter, at the same time, seems less dependent on a coincidently liberal supply of mineral constituents. So far, therefore, as the relative development of these two plants is concerned, the character of the herbage would be the better when the supply of nitrogen in the manure was not excessive, and that of mineral constituents liberal.

It is quite consistent with the character given to the Woolly soft-grass—namely, that it tends to usurp the land and is not reduced by cultivation—that the manures which give the greatest increase in the produce of hay should give so large a proportion of this ill-reputed element. If, indeed, this grass be really so objectionable as it has been stated to be, it would appear to be very desirable carefully to exclude it from the seed in laying down grass-land; otherwise—soil and other circumstances being adapted to its growth—the higher the manuring, and the larger the crop, the greater will be the proportion in it of this ill-famed plant.

3.—*Arrhœnatherum avenaceum*—*Fibrous-rooted, tall Oat-like Grass.*

The reputed characters of this grass are, that it yields a considerable quantity of foliage on the culms, which affords a good

* Under this very excessive manuring, the Rye-grass appeared to be somewhat displaced in its proportion by the rough Cock's-foot, which on that plot, and on that alone, was very luxuriant.

deal of leafy feed in the spring. It is said to reproduce rapidly after cutting. Its taste is rather bitter, but it is not disliked by cattle. It does not grow abundantly except upon poor soils, and is upon the whole of somewhat questionable value; it is, however, much grown in France. Its time of flowering is May.

This grass (in culm, &c.) stood third in amount on the unmanured land; it there constituted, however, only 6 per cent. of the total produce. Purely mineral manures raised its proportion to 9 per cent. Ammonium-salts, on the other hand, whether alone or in admixture with the mineral manures, seemed adverse to its predominance. Its proportion with such manures (see Plots 4, 10, and 13) was less than on the unmanured land. With farmyard manure, as with mineral manures, the proportion of the Oat-like grass was, as already alluded to, considerably increased. In fact, when the farmyard manure was used alone, the proportion of this grass in the total produce was more than double; and when with the addition of ammonium-salts, about three times as great as it was on the unmanured plot.

The general conclusion to be drawn regarding the relative development of this grass, when grown in a mixed herbage, would seem to be, that, with high artificial manuring of the kind that meadow-land is most likely to receive, it would not by such means alone be increased, but more probably diminished in its proportion in the total produce. But when farmyard manure is liberally used, or the soil is comparatively rich in mineral constituents, its development would appear to be encouraged. The result may be due, either to the special adaptation of rich mineral manuring to the luxuriant development of this grass, or to the fact that, with highly nitrogenous manures, its growth is somewhat checked by the greater luxuriance of the freer-growing grasses.

4.—*Anthoxanthum odoratum*—*Sweet-scented Vernal Grass.*

It is to the presence of this grass that the peculiar fragrance of newly-made hay is due. Its foliage is broad and coarse, but the plant is a scanty grower, though most luxuriant on wet soils. It is not relished by cattle, but is not objected to in small proportion; it is said to be best adapted for sheep. Upon the whole this grass takes rank somewhat low in the scale of the better grasses for permanent purposes. It flowers early, namely, in April and May.

Our separations showed 5½ per cent. of the Sweet-scented Vernal-grass (in culm), in the produce of the unmanured land. There was only one other instance—namely, that where mineral manures were used alone—in which the proportion amounted to 1 per

cent. The highly nitrogenous artificial manures appeared to be very adverse to its growth, nor did it succeed much better with farm-yard manure. As, however, this grass is a very early one, it is possible that, at the time of cutting, some of it would be past the stage at which it would be recognised in our samples.

The general result was, that the growth of the Sweet-scented Vernal-grass was much discouraged by such manures as greatly increased the amount and proportion of the Graminaceous hay-plants as a whole. Whether this is of consequence in any other point of view than that of fragrance, and whether in this one it is of real practical importance, is, perhaps, a question.

5.—*Agrostis vulgaris—Common, or Creeping-rooted Bent-Grass, or Black-switch, &c.*

This grass is said to flourish most on dry soils, to be a troublesome weed on arable land, to be disliked by cattle, and also by sheep, excepting sometimes in winter. It is, in fact, reputed as useless, and is recommended to be discouraged as much as possible. The time of flowering is May.

This grass amounted, in culm, to nearly 5 per cent. in the produce without manure. The proportion was, however, very much reduced under every one of the manured conditions. This result is certainly not to be regretted, if the characters of the grass are fairly given, as above. However, the *detached leaf and undeveloped stem* set down in the Table as "middling," was supposed to consist chiefly, and that set down as "coarse" more or less, of Bent-grass; and if this estimate be correct, it would appear, that there was a considerable proportion of this grass in this undeveloped condition on most of the plots; though it would be least in amount where either the farm-yard manure or the mixtures of mineral manure and ammonium-salts were employed. Fortunately, then, a grass having such a bad character as is attributed to the creeping-rooted Bent-grass seems to meet with the desired discouragement in those manures which develop more freely its more valuable congeners.

6.—*Briza media—Common Quaking-Grass.*

This grass is reputed to thrive best on poor soils, to afford a small yield, not to be liked by cattle, and to be discouraged by manuring. It flowers in June.

The Quaking-grass amounted to 2 per cent. in the sample of the produce from the unmanured land. It was only found in two cases in the manured produce, and then in even less proportion than in the unmanured. In the most highly-manured produce none whatever of it was to be found. The reduction or entire exclusion by manuring, is consistent with the character

of this grass as given above. It would seem, therefore, that it is not likely to be troublesome on good land, and that it is easy of expulsion by good manuring.

7.—*Cynosurus cristatus—Crested Dog's-tail Grass.*

This grass is said to have a wide range of soils, to grow on dry, damp, and even irrigated lands, and to vary in character accordingly. The opinions given respecting its value are somewhat conflicting. Some authorities consider its root-leaves, which are comparatively abundant, to be a favourable food for sheep, and that it is useful on soils and in seasons when other grasses are deficient. The stems seem, however, not to be eaten at all; and the more recent opinions, especially those of Professor Buckman, are quite against its utility. It is said, however, to be better for pasture than for hay; but as its character is to die out by improvement, its perhaps now established inferiority need not be much regretted. The time of flowering is June and July.

This crested Dog's-tail grass stood lowest of any among the grasses, in the scale of quantity on the unmanured land. It there amounted, in culm, to only 1 per cent. of the total produce. It was found in the manured produce in less proportion still, especially where ammonium-salts were used. It would appear, therefore, that where such manuring is employed as greatly increases the produce of hay, there will be little or none of this doubtfully useful element.

8.—*Dactylis glomerata—Rough Cock's-Foot.*

The Rough Cock's-foot is said to be very abundant and productive on good soils, particularly on those of a clayey nature, and to be much improved by cultivation. It grows well in moist and shady places, has broad foliage, is tufty, and reproduces rapidly after cutting. All stock like it, but particularly sheep, early in the season, before it has become hard and coarse. Its time of flowering is June and July.

Of this grass, in the condition of flowering and seeding stem, none whatever was found in the sample taken from the unmanured plot; none in that from the mineral manured plot; and none in that from either of the plots manured with farm-yard manure. It would appear, however, from the notes made by Professor Henfrey on the growing crop of 1857, as well as from the results of the partial separations made by ourselves when the crop of that year was cut, that the Rough Cock's-foot was far more predominant in the second than in the third year of the experiment. The conditions of growth of the samples in which it was found in the third year, are consistent with its apparent exclusion under the

conditions mentioned above. It was found to the amount of less than 2 per cent. (in flowering and seeding stem) in the sample grown by ammonium-salts alone, in less than 1½ per cent. in that by the same amount of ammonium-salts with mineral manures in addition, but to the extent of 20 per cent. when the double or excessive amount of ammonium-salts, together with the mineral manures, were employed. Where this very large proportion of Rough Cock's-foot was found in the produce of 1858, it was set down by Professor Henfrey in 1857, as "very fine," "abundant," and "ripe," and in the other cases as "backward." Consistently with this order of development of this plant according to manuring, we find a very small proportion of that leafy produce (the coarse) which was estimated to contain Cock's-foot, where the amount in flowering and seeding stem was so large, but more where the amount in flowering and seeding stem was only small. There was the most of it where the ammonium-salts were used alone; and it was in the sample of "coarse" leafy produce grown by that manure, that Professor Henfrey concluded there was the most of the Cock's-foot.

It appears that characteristically nitrogenous manures are favourable to the predominance of the Rough Cock's-foot. Where the supply of nitrogen is only moderate, it would appear to be outgrown and overpowered by the Rye-grass and Woolly soft-grass. It, in its turn, appears to overpower, particularly the Rye-grass, when the nitrogenous manure is very abundant. And, under the same conditions, it seems to reduce, and almost to exclude, several of the grasses of less value, and of less free growth. Thus, when the Cock's-foot was so abundant, there was less of the Oat-like grass found than on any of the other plots, no Sweet-scented Vernal-grass, very little creeping Bent-grass, no Quaking-grass, and scarcely any crested Dog's-tail. The reputed characters of the Rough Cock's-foot given above, are consistent with this luxuriant growth under high manuring, and with this apparent tendency to push out other plants by its own active vegetation. The Cock's-foot also affords an example of a useful grass much developed by those manures which yield a great bulk of total produce.

9.—*Poa pratensis*—*Smooth-stalked Meadow Grass.*

The Poa pratensis is said to be rather particular in its choice of situation, not to relish damp soils, but to thrive well in good and rather dry ones. It grows tuftily, and is said to have the tendency to banish other grasses. Its character is to yield a good early feed, and a free-growing and hardy after-grass. It flowers in May and June.

This grass was found only in the samples of the produce

grown by farm-yard manure. In these, however, its proportion was very considerable, amounting to about 15 per cent. of the whole where the farm-yard manure was used alone, but to only 10 per cent. where the farm-yard manure and ammonium-salts were used together. From our records relating to the produce of the second season, it appears that this Smooth-stalked Meadow-grass was detected on more of the plots in that season than in the third. Still, even then, it was found in very much larger proportion in the produce grown by farm-yard manure than in that by any of the other manures. This very marked development almost exclusively by farm-yard manure might lead to the conclusion, that part of the result was due to seed brought upon the land by the dung. But that the character of the manure, as such, had much to do with the effect, would seem from the fact, that the proportion of the Smooth-stalked Meadow-grass was considerably reduced when ammonium-salts were used in addition to farm-yard manure.

It would appear that the Smooth-stalked Meadow-grass is particular in the choice of manure as well as situation, and that artificial nitrogenous manures are either directly obnoxious to it, or cause it to be pushed out by those grasses whose luxuriance is greatly stimulated by such manures. Nor was this Poa perceptibly favoured in its growth by purely mineral manures. It might be supposed, therefore, that the carbonaceous organic matter of the farm-yard manure had something to do with the greatly increased development of the plant under the influence of that manure. This greatly increased development of the Smooth-stalked Meadow-grass under the influence of farm-yard manure appeared to be chiefly at the cost of the Woolly soft-grass —an exchange not at all to be regretted. The Oat-like grass is another grass much more valuable than the Woolly soft-grass, the proportion of which was much increased by farm-yard manure. This manure was seen, therefore, to develop two better grasses at the expense of a worse one. But it is to be regretted, that so useful a grass as the Smooth-stalked Meadow-grass should appear to be so nearly excluded under the influence of those so-called artificial manures, which are practically the most useful in increasing the produce of Graminaceous hay.

10.—*Bromus mollis—Soft or Downy Brome-Grass.*

This grass is described as a common weed in grass-land, the seed of which should be carefully excluded when sowing down. It is said to be innutritious, and even injurious to some animals. It flowers early in the season, but, after cutting, often seeds in the after-grass. It is found most in poor exhausted pastures.

With such characters as are here given to this grass, it is not

to be regretted that it was found in only one of our samples, and there in very small proportion. Professor Henfrey was, however, of opinion that its leaf occurred in a few of the samples of the "coarse" leafy produce.

11.—*Avena pratensis*—*Meadow Oat-Grass.*

This grass is best adapted to dry heathy places. It is of doubtful feeding value, though conflicting opinions are given respecting it. But, as it is said to be soon got rid of by good cultivation, its qualities are perhaps not of much consequence. It is the last on our list of *flowering and seeding Graminaceous plants.* It was found in the samples from three only of the seven plots, and in those in but insignificant amount. The largest quantity was found in the sample grown by the mixture of mineral manure and the excessive amount of ammonium-salts.

There are two other items to be briefly noticed before closing this *seriatim* account of the different descriptions of *Graminaceous* herbage found in the produce of the respective plots.

The proportion of the *leafy* produce set down in the Table as "*fine,*" varied extremely according to the manuring. It was very large where the ammonium-salts were used *alone;* and moderately so on the other plots where the total produce was not very large; but very small in the samples from the heaviest crops. We were quite unable to determine with any certainty to what plant or plants this "fine" leafy matter was to be referred. Professor Henfrey was, however, of opinion that some at least belonged to *Festuca Bromoides*, or Barren Fescue-grass.

"*Dead leaf and stem*" is the last item in the list of *Graminaceous* produce. Contrary to the fine leaf, this worthless dead matter occurred in very far the largest proportion where the artificial manuring was the highest, and the crops were the heaviest. Where the mineral manure and excessive amount of ammonium-salts were employed, this damaged portion of the produce amounted to nearly 12 per cent. of the whole; and where the mineral manure and the more moderate amount of ammonium-salts were supplied, to 7 per cent. Here, then, is experimental evidence showing a practical disadvantage in manuring so highly as to cause the crop to fall and die at the bottom before the bulk is fit for cutting.

II. Leguminous Herbage.

In the second season, 1857, four descriptions of Leguminous plant were distinguished on the experimental plots. These were *Lathyrus pratensis* (Yellow or Meadow Vetchling); *Lotus cornicu-*

latus (Common Bird's-foot Trefoil); *Trifolium pratense perenne* (Perennial Red Clover); and *Trifolium repens* (White or Dutch Clover). In the third season, 1858, very little of the last mentioned plant (Dutch clover) was observed on any of the plots; and the three other Leguminous plants seemed to be confined to fewer plots than formerly. Their limitation or extension, according to manuring, is very striking; and it is to the degree and conditions of their distribution, that attention is now to be directed. The results relating to these points are given in the third Division of Table IX.

1.—*Lathyrus pratensis—Yellow or Meadow Vetchling.*

This plant is described to grow naturally on either moist or dry soils, but generally on such as are of good quality. Cattle generally eat it with avidity; and hence it is recommended to be grown on very dry soils. The creeping nature of its roots unfits it for growth in rotation, but not so much for permanent meadow. It flowers in July.

The Meadow Vetchling occurred in rather larger proportion than either of the other Leguminous plants on the unmanured land. It there amounted, however, to only 2 per cent. of the total produce. On the *mineral manured plot* its proportion was raised to $4\frac{1}{2}$ per cent.; and on the plot with ammonium-salts alone, there were about $2\frac{1}{4}$ per cent. In the produce by the mineral manure and ammonium-salts together, none of this plant was observed. The produce by farm-yard manure gave about 2 per cent., and that by farm-yard manure and ammonium-salts little more than 1 per cent. of the Meadow Vetchling.

2.—*Lotus corniculatus—Common Bird's-foot Trefoil.*

This plant is said to grow abundantly on dry elevated pastures and heathy soils; and to be well deserving of cultivation on light dry, elevated inferior soils, on which it will yield a greater bulk of herbage than any of the cultivated clovers. It is supposed to be highly nutritious, and is eaten with avidity by cattle. From the great depths to which its roots penetrate, it is not liable to be injured by drought, and is hence enabled to retain its verdure after the grasses and other plants are burnt up. It flowers from June to August.

The Bird's-foot Trefoil was found in the produce of only two of the experimental plots, namely, the *unmanured*, and the *mineral-manured* ones.

3.—*Trifolium pratense perenne—Perennial Red Clover.*

There are several varieties of this plant, of which the most important are the Native perennial Red Clover, and the Common

perennial Red Clover or Cow-grass. They are too well known to every farmer to require description here.

Perennial Red Clover amounted to little more than 1 per cent. of the total produce on the *unmanured* land, but to nearly 18 per cent. of that grown by *mineral manures alone.* Not any of it was found in the produce by either ammonium-salts alone, or ammonium-salts in conjunction with mineral manures. There was little more than 1½ per cent. of it in the produce by farm-yard manure alone, and less than ½ per cent. in that by farm-yard manure and ammonium-salts.

The proportion of *total Leguminous Herbage* found in the produce of the *unmanured* plot, was about 5 per cent. This was made up of two parts Meadow Vetchling, rather less than two parts Bird's-foot Trefoil, and rather more than one part Perennial Red Clover. The produce by *mineral manures alone* was estimated to contain about 23 per cent. of Leguminous herbage, or about 4½ times as high a proportion as that grown without manure. These 23 parts comprised about 4½ parts Meadow Vetchling, about ½ a part of Bird's-foot Trefoil, and about 18 parts of Perennial Red Clover = 15 times as much as was found of it in the unmanured produce. The *ammonium-salts alone, reduced* the proportion of total Leguminous plant to little more than 2 per cent. in the produce, and then it consisted entirely of Meadow Vetchling: the Bird's-foot Trefoil and the Perennial Red Clover being apparently extirpated. And, in the produce by *mineral manures and ammonium-salts together, not any* Leguminous plant was to be found. The *farm-yard manure produce* contained less than 4 per cent. of Leguminous plant, which consisted of nearly equal parts Meadow Vetchling and Perennial Red Clover, to the exclusion of the Bird's-foot Trefoil. The *addition of ammonium-salts* to farm-yard manure, *reduced* the proportion of Leguminous herbage to about one-half. There was still no Bird's-foot Trefoil; and the Perennial Red Clover, as before, gave way more than the Meadow Vetchling under the influence of the ammonium-salts.

III. Miscellaneous Herbage, chiefly Weeds.

The fourth Division of the Table shows, that there were nine descriptions of these questionably useful, or even objectionable plants, detected in the samples from the experimental plots. Only seven of them were found together on the unmanured land, and a smaller number still on each of the manured plots. A few remarks will be made upon the characters, and conditions of occurrence, of these several plants, taking them in the order in which they occurred in the largest proportion on the unmanured land.

1.—*Plantago lanceolata—Rib-grass or Plantain.*

This plant is reputed to yield an herbage which, early in the season, is eaten by cattle, horses, and sheep; but which is disliked by them as the season advances. It is also objectionable on account of its spreading leaves, which tend to exclude other plants. It is natural to dry pastures. It flowers in June and July.

Nearly 16 per cent. of the produce *without manure* consisted of *Miscellaneous Weedy Herbage.* This comprised seven descriptions of plant, yet nearly 11 out of the 16 parts consisted of the Rib-grass. None of it was found in the produce grown by mineral manures alone; scarcely any in that by ammonium-salts alone; less still in that by the same amount of ammonium-salts and the mineral manures; and none at all in that by the double amount of ammonium-salts and the mineral manures. On the farm-yard manure plot less than 2 per cent. of the total produce, or only about one-sixth as much as on the unmanured land, consisted of the Rib-grass. The addition of ammonium-salts to the farm-yard manure, however, greatly increased the proportion of Rib-grass in the produce—namely, to 8¼ per cent.

It appears, then, that the Rib-grass, which was so prominent an item on the unmanured land, was greatly reduced in its proportion by farm-yard manure and ammonium-salts; still more by farm-yard manure alone; and nearly or entirely excluded by those artificial manures which increase the most the total produce of hay, and especially that of the Graminaceous herbage.

2.—*Carum carui—Common Caraway.*

This plant, though second in amount among the Miscellaneous Weedy Herbage on the unmanured land, amounted there to less than 2 per cent. of the total produce, and to about the same proportion in the produce of the two farm-yard manure plots. It was much diminished in its proportion, or excluded altogether, by the purely-artificial manures, especially when ammonium-salts were in relative excess.

3.—*Achillæa millefolium—Common Yarrow or Milfoil.*

The Milfoil is stated to be a grateful element in small admixture with other herbage for sheep; and it is recommended, therefore, to be sown with other seed for permanent sheep-pasture.

The Milfoil was found to the amount of somewhat more than 1 per cent. in the produce without manure. Its proportion was much diminished by farm-yard manure alone, mineral manure alone, and the mixtures of the mineral manure and ammonium-salts. Where the larger amount of ammonium-salts was used (with mineral manure) both the proportion and the actual

amount of this plant were considerably greater than where the smaller amount was employed with the mineral manures. Consistently with this effect of ammonium-salts, the proportion of the Milfoil was very much increased by the addition of these salts to farm-yard manure; and it was the greatest—in fact, then nearly three times as great as without manure—where the ammonium-salts were used alone.

If the characters of the Milfoil as sheep-food be such as above-described, it need not perhaps be much regretted that its growth seems to be favoured by nitrogenous manures.

4.—*Rumex acetosa—Sheep's-sorrel or Dock.*

This plant is undoubtedly objectionable. Unfortunately, however, it, as well as the Milfoil or Yarrow, was found in the produce of every plot; and, like the latter, it was increased in its growth by the use of ammonium-salts. It was more or less increased by these salts in whatever combination they were employed. Farm-yard manure alone also notably increased the proportion of the Dock in the produce; but farm-yard manure and ammonium-salts together increased it still more. With the latter combination the Dock amounted to more than 3 per cent. of the produce. As this obnoxious plant seems to be favoured in its growth by manuring, its expulsion must be attained by other means.

The remaining five plants that were detected in the samples are, without doubt, useless, if not obnoxious. They were each found, however, only on a few of the plots, and generally in but insignificant proportion.

5.—*Silene, or Catch-fly,*

was found in the unmanured produce only, and there to the extent of little more than ½ per cent.

6.—*Ranunculus—Crow-foot* (various species).

These plants were found in small quantity in the produce from the unmanured plot; in larger proportion in that grown by ammonium-salts alone; and in larger proportion still on the two plots with farm-yard manure. Their growth was, however, very much discouraged by the most productive artificial manures.

7.—*Luzula Campestris—Field Wood-rush.*

This rush was found only in the sample from the unmanured land, and there in very insignificant amount.

8.—*Veronica chamædrys—Germander Speedwell—*

was found only in the produce by mineral manures alone, and by farm-yard manure alone; and in both cases in very small amount.

9.—*Galium verum—Common Yellow-flowered Bed-straw, or Cheese-rennet.*

This plant was only found in the sample grown by the mixed mineral manure in conjunction with the lesser quantity of ammonium-salts.

It is possible that there were some other plants that either did not come within the reach of the scythe, or were otherwise excluded from our samples or determinations. Nor are the exact numerical proportions set down in the Table, to be considered, either within this or the other classes of plants, as anything more than approximations. Such, however, they undoubtedly are; and the facts brought out regarding the distribution, and development, of Miscellaneous Weedy Herbage, according to manure, are very clear and striking.

From this examination the very satisfactory result appears, that by far the larger *number* of the obnoxious or comparatively-useless plants occurred in the produce of the *unmanured* land. Taken collectively, too, their *proportion* was there very much larger than under any of the other conditions, excepting the one where the farm-yard manure and ammonium-salts were used together. It was chiefly the Rib-grass, and the Sheep's-sorrel or Dock, that were encouraged by this latter manuring. The *farm-yard manure alone* gave a larger proportion of Weedy Herbage than any of the *artificial manures;* but not half as much as either the *unmanured* land, or that manured by *farm-yard manure and ammonium-salts.* On all the artificially-manured plots the *number* of species found was reduced to about half that occurring on the unmanured land. In fact, those artificial manures which were the *most productive*, not only reduced the number of species of weeds considerably, but reduced the proportion of the total of such produce to about *one-tenth as much* as was developed *without manure.* It is certainly very satisfactory to find, that the most active artificial manures had the effect of very greatly *reducing* the proportion of the useless and obnoxious plants in the mixed herbage of the meadow. It is, on the other hand, somewhat discouraging to find, that the influence of *farm-yard manure*, which must be relied upon for the hay-crop to a certain extent, was not so favourable. It is to be hoped, that the facts which have been adduced regarding the conditions of development, and the amounts, of the Miscellaneous Weedy Herbage on the meadow

land, may fix on the mind of the farmer, the clear idea which the discussion of actual figures conveys, of the real amount of objectionable produce which he may frequently grow, unless proper means of reduction or eradication be had recourse to.

Attention may now be turned from the detailed consideration of the circumstances of development of the *individual plants*, to a statement of the more general character of the herbage under the different manurial conditions. In the Summary Table X. (p. 48) are recorded the main facts necessary to such a review; and the most prominent results already noticed in their place in more detail, will supply the remainder.

1.—*Total Graminaceous Herbage.*

At the time of cutting, 76 per cent. of the produce without manure consisted of Graminaceous herbage. At the same period of time, the proportion of such herbage in the total produce was increased to about 87¾ parts by farm-yard manure alone, and to 79¾ parts by farm-yard manure together with ammonium-salts. The produce by mineral manures alone contained scarcely 72 per cent. of Graminaceous herbage; 4 per cent. less, therefore, than the produce without manure. On the other hand, the produce by 400lbs. of ammonium-salts per acre, contained 89 per cent.; that by the same amount of ammonium-salts and mineral manures, 97⅓ per cent.; and that by the double amount of ammonium-salts and the mineral manures, also, 97⅓ per cent. of Graminaceous herbage.

But the *Graminaceous produce itself* varied extremely in character according to the manure employed. At a given period of the season, the Graminaceous herbage grown without manure, consisted of 66 per cent. of flowering or seeding stem, and 34 per cent. of leaf and undeveloped stem. At the same period, the Graminaceous produce by farm-yard manure, comprised nearly 80, and that by farm-yard manure and ammonium-salts, rather more than 80 per cent of culm, in flower or seed. Against these amounts without manure, or by farm-yard manure, the Graminaceous produce grown by the artificial manures alone was composed as follows:—That by the mineral manures alone contained 59 per cent. of flowering and seeding stem; that by ammonium-salts alone, only 40 per cent.; that by the same amount of ammonium-salts and mineral manure, 75 per cent.; and that by the double amount of ammonium-salts and mineral manure, 67 per cent., in flowering and seeding culm.

The general result is, *that those manures which much increased the produce of hay, at the same time very much increased*

its proportion of Graminaceous herbage. In fact, where the largest crops were obtained, namely, where the mixed mineral manure and ammonium-salts were used together, the proportion of the whole produce that was Graminaceous, was more than 97 per cent., whilst that without manure was only 76 per cent. The characteristic effects of nitrogenous manures to increase the proportion of leaves and shoots, and of mineral manures to determine more to flowering and seeding, are also strikingly illustrated. It will be obvious, therefore, that not only must the character of the gross produce be very different according to the description of manure employed, but that the proper time of cutting must vary very considerably to secure the majority of the herbage at any given point of ripeness.

But it has been seen, that the Graminaceous herbage varied much in character according to the manure, not only in regard to its proportion in the total produce, and to the proportion of the whole that was leafy and stemmy respectively, but also in the description or species of plants developed.

Under the particular conditions of soil, season, original distribution of plants, and other circumstances of these experiments, common Rye-grass was the most predominant of the grasses in the unmanured produce. The inferior Woolly soft-grass occurred in nearly an equal quantity; and then succeeded in lesser quantities, in the order here given, the tall Oat-like grass, the Sweet-scented Vernal-grass, the Creeping-rooted Bent-grass, the common Quaking-grass, and the Crested Dog's-tail—the last in very small amount. Farm-yard manure, which increased the actual amount and proportion of total Graminaceous herbage, gave a considerably increased proportion of Rye-grass and of tall Oat-like grass; a somewhat diminished proportion of the Woolly soft-grass; scarcely any of the other grasses found on the unmanured plot; but a very large amount of the valuable Smooth-stalked Meadow-grass, which was not found at all in the produce without manure. The addition of ammonium-salts to the farm-yard manure diminished the proportion of the more valuable Rye-grass, and Smooth-stalked Meadow-grass, but increased that of the tall Oat-like grass, and that of the inferior Woolly soft-grass.

Leaving out of consideration here, those artificial manures which did not much increase the total produce of hay, namely, the mixed mineral manure used alone, and the ammonium-salts alone, the general result with the more active artificial combinations was as follows:—The mixed mineral manure with the more moderate amount of ammonium-salts gave about 2½ times as much produce as the unmanured land, and the proportion of it that was Graminaceous was more than 97 per cent., instead of only 76 per cent. without manure. This enormously-increased Gram-

aceous produce contained twice as high a proportion of both the aluable Rye-grass, and the inferior Woolly soft-grass, as that with-at manure. The proportion of the Oat-like grass was, on the her hand, diminished; and, under the same conditions, all the her grasses were either very much reduced, or entirely excluded.

When the double and excessive amount of ammonium-salts as employed (with the mineral manure), the produce was about times as much as on the unmanured land, and the proportion it that was Graminaceous was, as in the last case mentioned, ore than 97 per cent. This greatly-increased Graminaceous oduce, under the influence of an excess of ammonium-salts, ntained a smaller proportion of the common Rye-grass than e unmanured hay. On the other hand, the proportion of the ferior Woolly soft-grass was very much increased. There was, oreover, with this manure a very large proportion of Rough ock's-foot—a grass which was found on very few of the other lots, and then in very small proportion. All the other grasses ere either excluded, or much reduced in amount, under the fluence of this excessive manuring.

2.—*Total Leguminous Herbage.*

The proportion of Leguminous herbage in the total produce ithout manure was about 5 per cent. Farm-yard manure re-uced the proportion, but not the acreage amount, of such produce; d the combination of farm-yard manure and ammonium-salts, ry considerably reduced both the actual amount, and proportion, this kind of herbage. In the produce by those artificial com-nations (mineral manure and ammonium-salts), which more an doubled or nearly trebled the amount of hay, and which creased the amount and proportion of the Graminaceous herbage strikingly, not a trace of Leguminous herbage was found. gain, ammonium-salts alone, which notably increased the raminaceous herbage, almost excluded the Leguminous. In e produce with this manure, neither Bird's-foot Trefoil nor erennial Red Clover was found; but the Meadow Vetchling oc-rred in about the same proportion as in the unmanured produce. n the other hand, mineral manures alone, which gave little or increase of Graminaceous produce, increased very strikingly oth the actual amount, and the proportion, of the Leguminous erbage. The proportion of total Leguminous herbage in the roduce by mineral manures alone was 23 per cent., instead of nly 5 per cent. in that without manure. The proportion of the ird's-foot Trefoil was diminished by the mineral manures; that f the Meadow Vetchling was notably increased; and that of the erennial Red Clover very considerably so.

The effect of *mineral* manures in developing a large proportion

of *Leguminous* herbage, and particularly of Clover, was therefore very striking. Artificial *nitrogenous* manures, on the other hand, seemed almost to extirpate such plants from the mixed herbage of the Meadow-land. These results are perfectly consistent with those observed in the manuring of Leguminous crops (beans, clover, &c.) when grown in *rotation*. Mineral manures have been found greatly to increase such crops, whenever a good plant could be once obtained and the season was not unfavourable. These crops, on the other hand—so highly nitrogenous both in their percentage composition, and in their acreage yield—have not been found to be specially benefited by the direct use of ammonium-salts; though nitrate of soda appears somewhat more favourable to their growth.

The general coincidence in the results obtained in regard to the action of characteristic descriptions of manure, on the agricultural plants included within each of these two great families (the Graminaceæ and the Leguminosæ), whether they be grown *separately and in alternation*, or *side by side in a mixed herbage*, is very striking. Such a coincidence, under such very varied conditions, must show, that the result is really due to the plants of the respective families requiring for their luxuriant growth a widely different relation of the mineral and nitrogenous supplies, respectively, *within the soil*. It cannot, under such circumstances, be attributed to mere local peculiarities, or to the mere accidental conditions of exhaustion induced by this or that agricultural practice. We have, then, in the facts observed in regard to the action of characteristic descriptions of manure in developing the different plants of which the *mixed herbage of a meadow* is made up, an unexpected, and very interesting confirmation, of those which have been established in regard to the development of the widely different plants which are grown *in rotation*. Such a coincidence must tend to inspire confidence in the conclusions arrived at in each of the widely different, and separately interesting, paths of inquiry.

3.—*Total Miscellaneous Herbage (chiefly Weeds).*

These plants were the most numerous in kind, and nearly in the greatest proportion, on the *unmanured* land. The produce without manure contained nearly 16, that grown by farm-yard manure and ammonium-salts more than 16, and that by farm-yard manure alone 7 per cent., of Miscellaneous or Weedy Herbage. In the produce without manure, about two-thirds of the amount of such herbage was Plantain or Rib-grass; and in that by the farm-yard manure and ammonium-salts about the same proportian of the whole consisted of Rib-grass and Sheep's Sorrel or Dock together, the former in the larger, and the latter in the smaller quantity. On the other hand, the produce grown by

those artificial manures which gave the largest crops of hay, contained less than 2 per cent., and a very few species, of Miscellaneous Weedy Herbage.

So much then for the results of this enquiry into the comparative development of the different plants of which the *complex herbage of a Meadow* is made up, according to the *manure* employed. The subject has been treated of with much more of system and detail than would otherwise have been necessary, inasmuch as, so far as we are aware, this is the first attempt that has been made, to trace the influence of special manures upon the individual plants of a complex herbage.

It must not be concluded, however, that the degree in which a particular description of manure develops any particular plant, when it is thus grown side by side with many others, is necessarily the same, either actually or relatively to those beside it, that it would be, were each plant grown separately, with such manure. The natural habit of a plant, its relative stage of progress at the different periods of the season, and its range of distribution both above and under ground accordingly, must indirectly affect the degree of luxuriance of the other plants associated with it. But, as it is in this *collective* way, that the various plants are grown in our permanent meadows, it is the action of different manures upon their development under these complex conditions, that is of the most interest to the farmer.

Again, the conditions of soil, situation, season, and of the original distribution and predominance of the respective plants, must, to a great extent, affect their relative development by different manures, when they are thus grown side by side. There is, moreover, evidence in the general observations made, or notes recorded, on the produce of the first two years in the experiments now in question, that there has been a *progression* from year to year, in the greater development of some plants, and in the reduction, or even exclusion, of others, the conditions of manuring remaining the same. It would appear, indeed, that great caution should be exercised in the application of artificial manures to *good feeding pastures*, lest the effect should be, to increase the growth of certain grasses of inferior quality, and to diminish or exclude those to which the high feeding value is attributable.

It is obviously very important, not only that the progressive action of the different manures should be carefully investigated for years to come, in the case of the experiments on the Rothamsted Meadow-land, but that experiments of a similar kind should be conducted by others, in different localities, and on different descriptions of soil. So far as our own part in the matter is concerned, we hope to follow up a subject which seems fraught with

so much interest both in a practical and scientific point of view. And we trust, that others will be found to lend their aid, in extending information in this important and hitherto untrodden field of inquiry.

From a review of the whole of the facts adduced in this Third Part of our Report, it would appear:—

1. That, however the produce of hay be considerably increased —whether by means of farm-yard manure alone, farm-yard manure and ammonium-salts, or artificial mixtures of suitable mineral manure and ammonium-salts—the proportion of the whole which will be *Graminaceous*, will be very much increased.

2. That the produce will be by far the *most Graminaceous* when the "*artificial mixtures*" are employed. In fact, when the increase of hay is obtained by artificial manures containing *both the necessary mineral constituents and ammonium-salts*—and it is then greater than under any of the other conditions—both the *Leguminous* and the *Weedy* Herbage are nearly excluded, and the produce is then, therefore, *almost wholly Graminaceous*.

3. That the *Graminaceous produce itself*, when grown by *farm-yard manure*, is less complex in character than that grown *without manure*; whilst that grown by the *most active artificial manures*, is *less complex still*.

4. That, up to an equal period of the season, the *Graminaceous* produce grown by the *active artificial manures*, will be in larger proportion in *flowering and seeding stem*, than that grown *without manure*; and that the produce grown by *farm-yard manure* will be in still larger proportion in that condition.

5. That the *description* of the produce grown by *farm-yard manure alone*, was upon the whole, superior to that grown *without manure*.

6. That when the crop was further increased, by the *addition of ammonium-salts to the farm-yard manure*, the character of the produce was somewhat deteriorated, both in regard to the *description* of the *useful plants* grown, and on account of the large proportion of *Miscellaneous* or *Weedy Herbage* then developed.

7. That, when in a *mixed mineral and ammoniacal manure* the ammonium-salts were *not used in excessive amount*, the herbage, which was then almost exclusively *Graminaceous*, and comprised also but *very few species*, nevertheless, included a considerable proportion of grasses of recognised good quality. But, *when excessive amounts of ammonium-salts were employed*, the character of the produce was deteriorated, both in regard to its *condition*, and to the *description of the grasses* that were developed.

Part IV.—Chemical Composition of the Hay.

Thus far it has been shown, that the produce of hay on permanent meadow land was more than doubled by means of manure alone. It has also been shown, that the description of the produce grown on the manured land was very different from that on the unmanured; and again, that it was widely different according to the kind of manure employed. The proportions respectively of the Graminaceous, the Leguminous, and the other Herbage, varied very considerably; so also did the kind and amount of the several plants comprised within each of these main divisions; and so also did the proportions of leaf, stem, and seed, and the condition of maturity.

Now the Leguminous herbage generally contains about twice as high a percentage of nitrogen as the Graminaceous. It also varies in composition in other respects. Leaves, stems, and seeds, differ much in composition from one another. And again, the degree of maturity of vegetable produce very much affects its percentage amount of certain important constituents. It will be obvious, therefore, that the composition of the complex produce —*hay*, must vary very considerably when grown by different manures.

The object of this Fourth and last Part of our Paper is to show the variation according to season, and manuring, in the *composition* of the hay grown on the different experimental plots, the particulars of the manuring and produce of which have already been so fully considered in other points of view.

In each of the three seasons over which the experiments have extended, the percentage amounts of *total dry substance*, of *mineral matter*, and of *nitrogen*, have been determined in the produce from each of the separate plots. The *woody-fibre* has been determined in the produce of each of the three years of those plots, which, in 1858, were selected for the botanical separations described in Part III. The *fatty matter* has been estimated in the produce of the same plots, but in that of the third season only (1858). Lastly, complete analyses of the *ashes* of the produce of five out of the seven plots selected for the botanical separations, and also of the mixed ash of the produce from all the plots, for each of the three years separately, have been made. The various analytical results will now be considered under separate heads.

1.—*Dry Matter.*

From each of the experimental plots, at the time the hay was carted, a sackful was taken, the samples being gathered from many parts of it. The whole of each of the specimens so taken

was then cut into chaff and well mixed. From the mixed sample in this condition two quantities of 25 ounces each were weighed, and in both of these the *dry matter* and the *mineral matter* were determined. Other samples were at the same time taken for the determinations of nitrogen, woody-fibre, &c.

The *dry matter*, which alone is at present under consideration, was determined by submitting the duplicate 25-ounce samples, for a sufficient length of time, to a temperature of 212° F. in a large water-bath. The *means* only, of the two determinations in each case, are given in Table XI. These will be quite sufficient for the elucidation of the points to which the results are applicable. But the individual determinations are given for reference in Table I. in the Appendix.

In the lowest division of Table XI. are given the *mean* percentages of Dry matter of all the specimens for each of the three seasons. The average percentage for all the specimens of 1856 was 79·3; that for 1857 was 86·8; and that for 1858 was 84·1. The mean percentage over the three years together was 83·4. There was, therefore, a variation in the average proportion of Dry matter in the hay of more than 7 per cent., according to *season*. The produce of 1857 gave a very high, and that of 1856 a very low proportion, of Dry substance.

The season of 1856 was, in every respect, ill adapted for high and dry condition of the hay. Accordingly, analysis indicates a very low percentage of Dry matter in the produce of that season. The seasons of both 1857 and 1858 were very much better in this respect. Of the two, the produce of 1857 contained considerably the higher proportion of Dry matter. But a comparative examination of the climatic statistics of these two seasons leads to the conclusion, that the higher percentage of Dry matter in the produce of 1857 is not so much due to the conditions during the last two or three weeks before cutting, as to the influence of climatic circumstances somewhat earlier, which developed more the seeding tendency in 1857 than in 1858.

Among the percentages of Dry matter relating to the produce of the *individual* plots, there is not a single instance that does not show the same general relationship between the characters of the three seasons on this point, as is indicated by the *mean* results only of each season.

Nor was there much difference between the average proportion of Dry matter in the specimens of the produce of each season taken at the time of carting, and that found in the bulk of the hay from the same (and adjoining land) after it had been some time in the rick. As a check on this point, samples were cut from the top to the bottom of the ricks which contained the mixed produce, both experimental and otherwise, of the seasons of 1857 and *1858* respectively, and the Dry matter was determined in them.

Plots, Nos.	(Per Acre, per Annum.)	1856.	1857.	1858.	Average of 3 Years.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	82·0	85·1	85·9	84·3
2	Unmanured (duplicate plot)	81·9	87·3	85·5	84·9
	Mean, or Standard Unmanured	81·9	86·2	85·7	84·6
3	2000 lbs. Sawdust	80·7	87·7	84·4	84·3
4	200 lbs. each, Sulphate and Muriate Ammonia	80·0	86·7	84·1	83 6
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	79·6	87·6	83·9	83·7
6	275 lbs. Nitrate of Soda	...	...	84·8	...
7	550 lbs. Nitrate of Soda	...	...	85·8	...
	Mean	80·5	87·0	84·8	84·0
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	80·2	86·7	85·6	84·2
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	80·5	86·8	84·1	83·8
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	79·0	87·0	82·1	82·7
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	77·3	87·2	83·8	82·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·2	86·8	82·4	82·8
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	78·1	85·9	80·7	81·6
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	86·4	...
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	85·2	...
	Mean	79·0	86·7	83·1	83·0
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	76·1	87·3	84·6	82·6
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	79·6	86·2	82·7	82·8
	Summary.				
	General Means for the Experimental Specimens	79·3	86·8	84 1	83·4
	Mixed Hay from the same Meadow; taken out of the rick December 1858	...	87·2	83·8	...

* For full description of the "Mixed Mineral Manure," see page 6.

The results are given at the foot of Table XI.; and the comparison afforded is as follows:—The average percentage of Dry matter in the experimental specimens of 1857 was 86·8; and that in the hay taken from the rick of that year (sampled Dec. 1858) was 87·2. Again, the average percentage of Dry matter in the experimental specimens of 1858 was 84·1; and that in the hay from the rick of that year (also sampled Dec. 1858) was 83·8. The general characteristics of the produce of the *different seasons*, in regard to its percentage of *Dry matter*, are, therefore, correctly represented in the results given in the Table in reference to the experimental specimens.

The differences in the percentages of Dry matter in the hay, due to different *manuring*, are by no means so great as those due to variation of season or climatic circumstance. Still the general tendency of the influence of characteristic descriptions of manure is clearly discernible. The indications of the coincident comparative conditions of the produce, according to the manure employed, are also consistent.

Up to the period at which the crops were cut, the use of *ammonium-salts* had the almost invariable effect of giving a produce which contained a somewhat lower proportion of Dry matter, than that grown under otherwise exactly comparable conditions. Such is seen to be pretty uniformly the result, whether we compare the produce by ammonium-salts alone with that without manure; that with ammonium-salts and sawdust, with that with sawdust alone; that with ammonium-salts and mineral manure, with that by mineral manure alone; that with ammonium-salts, sawdust and mineral manure, with that by sawdust and mineral manure alone; or that with the larger amount of ammonium-salts and mineral manure, with that by the smaller amount of ammonium-salts and the same mineral manure. A similar result is observed too, in two years out of the three, where ammonium-salts were used in addition to farmyard manure. The results in the Table which appear to be exceptional to this generalisation in regard to the influence of ammonium-manures upon the percentage of Dry matter of the hay taken at a given period of the season, occur in some of the cases with the artificial manures in 1857; and in 1856, in the case where the ammonium-salts were used in addition to farmyard manure.

Ammonium-salts which have thus been seen, other things being equal, to give a produce which contains a comparatively low percentage of Dry matter, gave, it should be remembered, also a much increased bulk and weight of hay over a given area: hence, even supposing that the description of the herbage, and the condition of maturity of the plants, were the same where the larger crops were grown with ammonium-salts, and the smaller ones without them, we should still expect that the larger produce

would dry somewhat less, exposed to equal circumstances during the making. But the description of the herbage, and its degree of forwardness, have been seen to vary very much according to the manure employed. The produce grown by ammonium-salts gave a much larger proportion of Graminaceous plants than that grown without them. The mere flowering and seeding stems of this Graminaceous herbage, would contain a higher percentage of Dry matter than the leaves and younger shoots. But besides the detached leafy matter, the larger culms grown by the ammonium-salts, were themselves more luxuriant and succulent, and carried more green leaves and shoots than the smaller ones grown under otherwise comparable conditions, but without the ammonium-salts.

It is obvious, then, that the percentage of the *Dry matter* in such complex and heterogeneous produce as *hay*, is dependent on too many coincident causes, to be of itself any unconditional indication of the character, or degree of maturity, of such produce.

The percentages of *mineral matter*, and of *nitrogen*, in the dry substance of the hay grown by the different manures, will be some further guide as to the comparative degrees of succulence, or maturity, of the produce developed under the different conditions.

2.—*Total Mineral Matter (Ash).*

The *mineral matter* was determined by burning to ash the portions of hay which had been dried at 212° F., and re-weighed for the determination of the dry matter. The burning was conducted on sheets of platinum placed in cast-iron muffles, heated by coke. Duplicate determinations were always made. The *mean* percentages only, of the two determinations, are given in Table XII.; and the *individual results* are recorded for reference in Tables II., III., and IV., in the Appendix.

In *ripened* produce, such as our crops of grain, the relations of the percentages of *mineral matter* in the dry substance in a series of comparable specimens, are pretty clear indications of the relative degrees of elaboration and ripeness of such produce. Other things being equal, the smaller the percentage of Mineral matter in the dry substance, the more highly elaborated, or the riper, is the specimen. The percentage of *nitrogen* in our ripened grain-crops is affected in a somewhat similar manner. Other things being equal, the lower the percentage of Nitrogen in the dry substance, the higher, taking the average of seasons, will be the condition of maturation of the produce.

The like generalisation appears to be more applicable to the composition of the complex and but partially ripened produce—*hay*, than would perhaps have been anticipated.

Experiments with Different Manures on Permanent Meadow Land.

Table XII.—Percentages of Mineral Matter (Ash) in the Hay (Means of Duplicate Determinations).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.				Percentages in the Dry Substance of the Hay.			
		1856.	1857.	1858.	Average of 3 years.	1856.	1857.	1858.	Average of 3 years.
	Series 1.—Without Direct Mineral Manure.								
1	Unmanured	6·26	5·63	5·70	5·86	7·64	6·61	6·64	6·96
2	Unmanured (duplicate plot)	6·64	5·71	5·56	5·97	8·10	6·54	6·50	7·05
	Mean, or Standard Unmanured	6·45	5·67	5·63	5·91	7·87	6·57	6·57	7·00
3	2000 lbs. Sawdust	6·62	5·64	5·61	5·96	8·20	6·43	6·65	7·09
4	200 lbs. each, Sulphate and Muriate Ammonia	6·44	5·48	5·14	5·69	8·06	6·32	6·11	6·83
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·01	5·51	5·83	5·62	7·54	6·29	6·35	6·73
6	275 lbs. Nitrate of Soda	...	...	5·73	...	...	...	6·75	...
7	550 lbs. Nitrate of Soda	...	...	5·38	...	...	...	6·26	...
	Mean	6·38	5·59	5·67	5·79	7·92	6·40	6·45	6·91
	Series 2.—With Direct Mineral Manure.								
8	"Mixed Mineral Manure"*	6·92	6·16	6·48	6·52	8·63	7·10	7·57	7·77
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	7·21	6·60	6·47	6·79	9·08	7·60	7·70	8·13
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·77	6·28	6·53	6·53	8·58	7·31	7·95	7·91
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	7·03	6·42	6·80	6·75	9·09	7·36	8·11	8·19
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·72	6·72	6·68	6·71	8·49	8·49	8·11	8·36
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·57	6·42	6·35	6·45	8·41	7·47	7·87	7·92
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	6·40	...	...	...	7·40	...
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	6·52	...	...	...	7·65	...
	Mean	6·89	6·43	6·53	6·62	8·71	7·54	7·79	8·01
	Series 3.—With Farmyard Manure.								
16	14 tons Farmyard Manure	7·29	6·51	6·72	6·84	9·58	7·45	7·95	8·33
17	14 tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	7·52	6·45	6·74	6·90	9·45	7·46	8·14	8·35
	Summary.								
	General Means for the Experimental Specimens	6·80	6·15	6·16	6·37	8·58	7·15	7·73	7·82
	Mixed Hay from the same Meadow; taken out of the rick, December, 1858	..	5·58	5·73	..	..	6·40	6·84	...

* For full description of the "Mixed Mineral Manure," see page 6.

The hay-season of 1856 was wet and cold, and the produce it yielded contained a very low percentage of dry substance. The hay-seasons of 1857 and 1858 were, upon the whole, much drier and warmer, and, accordingly, the percentages of dry substance in their produce were much higher. Coincidently with the much lower percentage of dry matter in the produce of 1856, there was a considerably higher percentage of Mineral matter in the dry substance of that produce than in that of either 1857, or 1858. Again, the average percentage of dry substance in the hay was lower in the produce of 1858 than in that of 1857; and in accordance with this, the average percentage of Mineral matter in the dry substance of the produce of 1858, was higher than in that of 1857. It appears then, that, *comparing season with season*, the general result on this point in regard to hay, is in conformity with that generally observed in the case of more equably ripened produce. That is to say, the lower the condition of elaboration of the constituents of the produce, the lower is the percentage of the Dry substance, and the higher the percentage of the Mineral matter in that dry substance.

So much for the results in regard to the percentage of *Mineral matter* in the hay, as affected by *season*. We turn now, to the influence of *manuring* on the composition of the hay in regard to Mineral matter.

When it is borne in mind—that the proportion of the produce which will consist of Graminaceous, Leguminous, or other herbage, —that the proportion of the respective plants comprised within each of these main classes—that the proportion of each that will be in leaf and culm respectively—and that the condition of maturity at any given time—will vary very considerably according to the manure employed, it will be obvious that the variations in the percentages of Mineral matter, due to *manuring*, will be the resultants of many coincidently operating causes. On these points it may be observed—that the dry substance of Leguminous herbage contains on the average about 1⅓rd time as high a percentage of Mineral matter as that of Graminaceous herbage; that the dry substance of the leafy portion of the produce contains a higher percentage than that of the stemmy portion; and lastly, that the riper the produce the lower will be the percentage of Mineral matter in the dry substance. But again, in our green and unripened produce more especially, the *percentage* of Mineral constituents, as well as the actual amounts assimilated over a given area of land, are very much affected by the deficiency or liberality of their supply, in available form, within the range of collection of the growing crop.

The Table (XII.) shows that where no mineral manure was employed—and especially where nitrogenous manures were used alone, and the production thus pushed to the extreme limit of

the available supplies of the mineral constituents of the soil itself—the percentage of Mineral matter, in the dry substance of the hay, was comparatively low. A somewhat similar result has been observed in the case of grain-crops grown under similar circumstances. In illustration of the point in regard to the hay, it is seen that, whilst the average percentage of Mineral matter in the dry substance of the specimens grown without mineral manure was 6·91, that taking the average of the cases where artificial mineral manure was employed, was 8·01. It is true that, in those cases where mineral manure was employed with ammonium-salts, the *stemmy* produce was somewhat less ripe, and hence, so far, the percentage of Mineral matter in the dry substance would be expected to be comparatively high. On the other hand, the produce in these cases was almost entirely Graminaceous, and the Graminaceous produce itself contained a large proportion of stem to leaf, and both of these circumstances would, other things being equal, tend to a low percentage of Mineral matter in the dry substance. In fact, upon the whole, the evidence is pretty clear, that the lower percentage of Mineral matter in the dry substance of the produce grown without mineral manure, was due to a relative deficiency of available mineral constituents in the soil. The direct influence of the supply of mineral constituents by manure, upon the assimilation of them by this voracious crop, will be further illustrated presently, when speaking of the *composition of the ash* of the produce grown by the different manures.

Where the mineral manures were used alone, more than one-fifth of the produce consisted of Leguminous herbage. Hence, it might be supposed, that the percentage of Mineral matter in the gross produce, or hay, would be higher than where nitrogenous manures were also employed, and the produce was almost entirely Graminaceous. Again, where the mineral was used without the nitrogenous manure, the proportion of the Graminaceous produce that was leafy was much greater than where nitrogenous manures were also used. This circumstance, again, would tend to a high percentage of Mineral matter in the produce grown by the mineral manures alone. But the fact was, that the percentage of Mineral matter in that produce was comparatively low. The result was, doubtless, due to the fact, that a large proportion of this produce by mineral manure alone, was much riper than that grown by the mineral and nitrogenous manures combined.

It appears then, that in the case of the complex and unripened produce—*hay*, the description of the herbage, the character of development, the stage of progress at which the plants are cut, and the supplies within the reach of the growing crop, all have a marked influence upon the percentage of *Mineral matter* in the produce. The effects of different manure, in one and the same

n, upon this percentage are, therefore, at least complicated, ; indirect. Nor do the relative percentages among a series ecimens so clearly indicate the comparative conditions of ration and maturation merely, as they generally do in the of professedly ripened produce.

3.—*Constituents of the Ash.*

ıe influence of the artificial supply of mineral constituents . the total amount of them assimilated by the crop over a ı area of land, has been illustrated in Part II. of our Report. influence of such supply upon their percentage in the dry tance of the produce has now been shown. By the aid of plete analyses of the *ashes* of the produce of some of the ex- nental plots, further light will be thrown on the effects of a al provision of mineral constituents in the soil on the mineral position of the crop.

ı the first Division of Table XIII. is given the *percentage osition* of the ashes from the produce of five of the experi- tal plots; in the second Division of the Table the amounts of of the several mineral constituents in the average annual *total uce* per acre on each of the plots; and in the third Division the *ase* in the amounts of the several mineral constituents obtained, ıcre, in the crop, under the influence of the different manures. he plots selected were—the unmanured; the one with am- ium-salts alone; the one with mixed mineral manure alone; with the mixed mineral manure and the smaller amount of ıonium-salts; and that with the mixed mineral manure and larger, or double amount of ammonium-salts. In the case ıch of the 5 plots, an equal mixture of the ash of its produce ach of the three years was operated upon. In this way the age effect of each condition of manuring upon the mineral position of the crop is taken over a three-years' continuance ıat condition.

he ash-analyses were made in the Rothamsted laboratory, by Robert Warington, jun.; and we are glad to take this oppor- ty of expressing our full confidence in the accuracy of his results. he facts which the figures in the Table disclose are very in- sting. But our comments on them must be very brief, and onfined to their practical bearings.

; has been shown in Parts I. and III. of our Paper, that ıonium-salts alone gave an almost entirely Graminaceous luce, but that that produce was stunted, very dark green, leafy, , comparatively, not much more in weight per acre than that ıout manure. Mineral manures alone, on the other hand, in- sed the weight of produce somewhat more than the ammonium- ı alone; but the increase in this case was chiefly Leguminous ıage—the Graminaceous herbage benefiting but little by this

EFFECTS of DIFFERENT MANURES on the MIXED HERBAGE of GRASS-LAND.

TABLE XIII.—PERCENTAGE COMPOSITION of the ASH; and QUANTITIES of the several MINERAL CONSTITUENTS in the Total Produce, and in the INCREASE by MANURE, per Acre.

	Percentage Composition of the Ash.					Mineral Constituents in Total Produce (lbs.).					Mineral Constituents in Increase (lbs.).			
	No Manure.	Ammonium-salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonium-salts. (82 lbs. N.)	Mineral Manure and Ammonium-salts. (164 lbs. N.)	No Manure.	Ammonium-salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonium-salts. (82 lbs. N.)	Mineral Manure and Ammonium-salts. (164 lbs. N.)	Ammonium-salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonium-salts. (82 lbs. N.)	Mineral Manure and Ammonium-salts. (164 lbs. N.)
Peroxide of Iron	0·13	0·12	0·31	0·45	0·52	0·2	0·3	0·7	1·9	2·4	0·1	0·5	1·7	2·2
Lime	14·98	13·85	13·38	9·60	8·65	23·7	31·0	32·4	41·7	39·8	7·3	8·7	18·0	16·1
Magnesia ...	4·14	4·70	3·70	3·41	3·98	6·6	10·5	9·0	14·8	18·3	3·9	2·4	8·2	11·7
Potash	20·40	17·09	29·77	28·08	28·89	32·3	38·2	72·2	121·9	132·9	5·9	39·9	89·6	100·6
Soda	8·43	10·31	4·58	7·05	8·49	13·3	23·0	11·1	30·6	39·0	9·7	−2·2	17·3	25·7
Phosphoric Acid	4·86	4·64	6·67	6·30	5·97	7·7	10·4	16·2	27·4	27·5	2·7	8·5	19·7	19·8
Sulphuric Acid	6·09	7.56	7·78	6·27	5·71	9·6	16·9	18·9	27·2	26·3	7·3	9·3	17·6	16·7
Chlorine	6·22	14·66	6·52	16 49	19·93	9·8	32·8	15·8	71·6	91·7	23·0	6·0	61·8	81·9
Carbonic Acid	5·62	3·21	6·63	1·87	1·73	8·9	7·2	16·1	8·1	7·9	−1·7	7·2	−0·8	−1·0
Silica	25·91	21·17	18·82	18·57	15·89	41·0	47·3	45·6	80·6	73·1	6·3	4·6	39·6	32·1
Sand	1·41	1·95	0·82	2·84	2·98									
Charcoal	3·19	4·08	2·54	3·04	2·13									
	101·38	103·34	101·52	103·97	104·87									
Deduct O = Cl.*	1·40	3 31	1·47	3·72	4·50									
Totals ...	99·98	100·03	100·05	100·25	100·37	153·1	217·6	238·0	425·8	458·9	64·5	84·9	272·7	305·8

* In the absence of knowledge which chemistry does not supply, as to the state of combination, either in the plant itself, or in the ash, of the several constituents determined in a plant-ash, it is considered far better to make no assumptions on the point. It is, moreover, far more convenient, both for the comparison of the composition of one ash with that of another, and for the purposes of any calculations with a practical view, to represent the whole of the sodium and potassium as soda and potash; instead of part as such, and part as chlorides, as is frequently done when chlorine is present. This method, of course, requires the deduction from the sum of the constituents, of an amount of oxygen equivalent (chemically) to the total chlorine.

anure, excepting in forwardness and seeding tendency. But ıe mixture of the two manures—ammonium and mineral—gave ı enormous increase of crop, and the amount of mineral con-ituents taken off an acre of land, under the influence of the com-ination, was nearly twice as great as that in the crop by either f the manures used separately. It was quite obvious, that here the *ammonium-salts* were used *alone*, the available sup-ly of some of the necessary *mineral* constituents fell short of ıe amount required for a more abundant crop. It was ually clear, that where the *mineral manures* were used *alone*, ıere was a deficiency of *nitrogen* available for the increased rowth of the Graminaceous herbage. The results in the Table ıow that it was chiefly for its supply of *potash*, and next for ıat of *phosphoric acid*, that the mixed mineral manure was so fficacious in increasing the growth of the *grasses*, when there as a sufficiency of available *nitrogen* within the soil. They lso point to a probable deficiency of soluble *silica* in the case f the heavier crops.

To turn to the figures in the Table: the most striking point f contrast afforded by the view of the results of the five analyses iven side by side, is the very great increase in the percentage f *potash*, wherever the mineral manure containing it was em-loyed. There is, at the same time, always a diminution in the *oda*, either in its actual percentage, or in its proportion to that of he potash, or in both these points of view. This was the case, otwithstanding that soda as well as potash was liberally supplied ı the mineral manure. The preference of the growing plants ır potash rather than soda is sufficiently manifest. And judging om the analogy of other crops it may almost certainly be con-luded that, if all the plants of the hay had been allowed to fully ipen, the ash would then have contained but very little soda, if ny at all. The increase in the percentage of *potash* in the ash, here it was supplied in manure, is at the expense of the lime nd magnesia, though these constituents were also supplied in the ıixed mineral manure. In fact, the ash both of the produce ithout manure, and of that by ammonium-salts alone, gave a ɔmewhat higher percentage of both lime and magnesia than even here the mineral manures alone were used, and the produce con-ıined so much Leguminous herbage, the ash of which is richer ı lime and magnesia than is that of the Grasses proper. The ercentage of lime more particularly, was still further reduced, hen the ammonium-salts were mixed with the mineral manure, y which the growth of the Grasses, demanding so much potash, as so much increased.*

* It is seen that wherever the ammonium-salts were employed, which consisted of a mixture of the sulphate and hydrochlorate, the amount of *chlorine* ı the ash is very much increased. This constituent, like soda, is found only

The percentage of *phosphoric acid*, as well as that of potash, was increased notably, though not in so great a degree, where the mineral manure containing it was used.

The percentage of *sulphuric acid* in the ash is pretty uniform throughout, though it was supplied largely both in the ammonium-salts and in the mixed mineral manure. Whether or not, the whole of the sulphuric acid found, existed *as such* in the plant, in combination with bases, or whether, on the other hand, there has been any loss of it, or of sulphur in some form, during the incineration, may be a question. It is, at any rate, worthy of remark how very much larger is the proportion of *chlorine* found in the ash of this succulent produce wherever it was used in manure, notwithstanding that this substance (chlorine) may be supposed to be in a far less degree than sulphur or sulphuric acid, if at all, essential to the elaboration of the final products of the plants.*

Carbonic acid is seen to be in the largest proportion in the produce grown without manure, and in that by mineral manures alone. The Carbonic acid is the product of the incineration of some other organic acid. Its comparatively large amount in the ash of the produce of the two plots mentioned is due to the Leguminous and other non-Graminaceous herbage, occurring in large proportion on those plots. The ash of such herbage (the non-Graminaceous) contains, indeed, little or no silica, and frequently a great deal of Carbonic acid due to salts of organic acids.

The percentage of *silica* is, nevertheless, much higher in the ash of the produce grown without manure than in that grown by any of the artificial manures now in question. The percentage of *silica* in the ash is the less where the proportion of the Graminaceous herbage—which so peculiarly requires it—is the greater. And where the total Graminaceous herbage was thus the greater, it was also in the larger proportion in flowering and seeding stem; and as the stem increases, so, when not in defect, does the proportion of *silica*. It is true that where the Graminaceous produce was so large, and the proportion of it that was in flowering and seeding stem was also large, those stems were not so

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seldom, or in small quantity, in the ash of perfectly-ripened vegetable produce. It probably serves more as a vehicle of bases, than as an essential constituent of any of the final products of the organism.

* The fact, that in such highly siliceous ashes the amounts of chlorine should not only in some cases be very large, but that the variations in amount should have such very obvious connection with the manurial conditions supplied, is quite in accordance with the experiments of Mr. Way, showing that a loss of chlorine need seldom be feared when the process of incineration is carefully conducted. It is true, that the percentage of chlorine is the lowest where that of the silica is the highest, and that of the chlorine is the highest where that of the silica is the lowest; but the differences in the proportions of the respective constituents have, at the same time, as has been said, a very obvious connection with the known conditions of their supply or deficiency.

ipe as were those of the smaller Graminaceous crops; and it is s the Graminaceous plants progress to ripeness, that their ashes ncrease so much in percentage of *silica*. It would appear from hese considerations, that there was a deficient supply of *available ilica* for the greatly-increased growth. But a better view of the robable mineral requirements, or deficiencies, of the crop, will e gained by attention to the actual or increased amounts of the everal constituents in the *acreage produce* under the different nanuring conditions, as shown in the second and third Divisions f the Table (XIII.).

By the use of *ammonium-salts alone*, the amount of total nineral constituents taken off in the crop is about 1½ time s much as without any manure at all. From the obvious imit that there was to the Graminaceous increase by ammonium-alts alone, it is assumed that, in the case of some of the mineral onstituents of the soil, its supplies were drained to the utmost hat the range of distribution of the underground feeders of the lant would permit. Supposing this to be the case, it is seen hat the gain in both *potash* and *silica* was proportionally less han that of any other important constituent. But, as soon as otash is added in manure, even though without ammonium-alts, the acreage amount of it in the crop is increased in larger roportion than that of any other important mineral constituent, xcept phosphoric acid. The *silica*, which was not supplied in he manure, was comparatively but little increased in the pro-uce. When the ammonium-salts as well as mineral manure ere employed, the amount of *potash* in the acreage produce as nearly twice as much as when the mineral manures were sed alone; and it was from 3 to 4 times as much as when no anure at all, or ammonium-salts alone, were employed. Under he same circumstances, the acreage amount of *phosphoric acid* ncreased in almost an equal degree. So also did that of the *sul-huric acid*. The *silica* even, was about doubled; though there as no supply of it in manure. And, lastly, the *magnesia*, but specially the *lime* (though both were supplied in the manure) ncreased very much less in acreage amount than the potash.

From the whole it appears, that the much less acreage produce f hay, when the ammonium-salts were used alone, than when they ere used in conjunction with the mixed mineral manure, was due o a deficiency of available *potash* and *phosphoric acid* within the ange of the roots of the crop. It also appears probable, that here was a relative deficiency of available *silica*, notwithstand-ng that the range of collection of the roots of the crop would be onsiderably increased where the ammonium-salts and the non-iliceous mineral constituents were employed. It is true that he *acreage* yield of *silica* was considerably increased where the

larger crops were grown; though it was so not at all commensurately with either the potash or the phosphoric acid. How far the increased amount of *silica*, such as it was, was due to its being liberated in available form by the chemical action of the constituents of the manures employed, or how far only to the increased distribution and range of collection of the roots of the more actively growing crop, we do not decide.

To call to mind even more clearly than by the above statements how great is the drain upon the soil, more particularly of potash, phosphoric acid, and of silica, by a heavy hay-crop, it will be useful to quote here a few figures from the Table.

Whilst the unmanured produce contained only 32½ lbs., and that by ammonium-salts alone only 38¼ lbs. of *potash*, that grown by the mineral manure alone (supplying potash) contained 72¼ lbs., that by the mineral manure and smaller amount of ammonium-salts nearly 122 lbs., and that by the mineral manure and the larger amount of ammonium-salts nearly 133 lbs. of potash, per acre, annually.

The *phosphoric acid* was increased from about 7¾ lbs. per acre per annum without manure, to scarcely 10½ lbs. with ammonium-salts alone, to 16¼ lbs. with mineral manure alone, and to about 27½ lbs. by the mineral manure and ammonium-salts together.

The *silica* amounted to 41 lbs. per acre per annum in the produce without manure, to 47⅓ lbs. in that by ammonium-salts alone, to nearly 45⅝ lbs. in that by mineral manure alone, to 80⅜ lbs. in that by the mineral manure and the smaller amount of ammonium-salts, and to a little more than 73 lbs. in that by the mineral manure and the larger amount of ammonium-salts.

We have already prominently called attention to the fact that the hay-crop, both from the large amount of mineral constituents it generally carries from the land, and from the generally more inadequate return of them by the home or other manures, is liable to be much more exhausting to the soil than the rotation crops of a farm. It has been stated, too, that *potash* was perhaps the constituent most likely first to show a deficiency. These ash-analyses, and the discussion to which they have led, cannot fail to impress upon the mind of the farmer still more forcibly the necessity of a due return to the land, at least of *potash* and *phosphoric acid*, if not even of available *silica* (which would be accomplished by farmyard-manure), if he would hope to obtain anything like maximum crops of hay, year by year, by the aid of artificial nitrogenous manures.

It has just been seen how very variable is the composition of the *ash* of the mixed herbage of meadow-land according to the *manure* employed. It has before been shown that the composi-

tion of the total mixed produce, or *hay*, varied very much according to *season*—both in regard to the percentage of Dry substance, and to that of the Mineral matter in that Dry substance. It will also presently be seen that the percentages of total Nitrogenous compounds likewise varied very much according to *season*. The *composition of the ash* does not, however, appear to be so much affected by variation in *season* as, from the influence of the latter on the composition of the hay in other points of view, might have been anticipated.

The much less effect of variation in *season*, than in *manuring*, on the *composition of the ash* of the experimentally-grown hay, is illustrated by the results given in Table XIV., which now follows:—

TABLE XIV.—Showing the COMPOSITION of the ASHES of MEADOW-HAY grown Experimentally in different Seasons.

	Mixed Ashes of the Produce by 16 different Manures in each Year.			
	1856.	1857.	1858.	Calculated Mean (1856-7-8).
Peroxide of Iron	0·14	0·33	0·25	0·24
Lime	13·02	12·13	11·92	12·36
Magnesia	3·59	3·93	3·97	3·83
Potash	26·83	26·43	25·26	26·17
Soda	6·40	7·45	9·58	7·81
Phosphoric Acid	5·59	5·68	5·52	5·60
Sulphuric Acid	6·02	7·14	7·18	6·78
Chlorine	11·37	12·15	12·25	11·92
Carbonic Acid	3·37	2·74	2·73	2·95
Silica	22·28	19·93	20·23	20·81
Sand	2·15	2·89	2·29	2·44
Charcoal	2·22	2·22	2·17	2·20
	102·98	103·02	103·35	103·11
Deduct O = Cl*	2·56	2·74	2·76	2·69
Totals	100·42	100·28	100·59	100·42

* See note at foot of Table XIII.

In the first column of the Table is given the composition of an equal mixture of the ashes of the produce from all the experimental plots in 1856; in the second column, the composition of a similarly mixed ash from the produce of all the plots in 1857; and in the third column, the composition of the mixed ash from all the plots in 1858. The fourth column gives the calculated mean of the three analyses.

The uniformity in the composition of the three mixed ashes,

representing as they do the percentage mineral composition of the produce of three very different seasons—the characters of which differed so widely in several other respects—is somewhat remarkable. The differences are indeed too slight to justify the deduction from them of any very defined conclusions. Still, it may be observed, that the tendency of the variations is to show a scarcely maintained, and in some cases an even diminished proportion, of those constituents which may be considered the most characteristic of the hay crop, when it is supplied liberally with all the necessary mineral constituents. Thus, the proportion of phosphoric acid is about equal in the three seasons, whilst that of the lime, the potash, and the silica, show a tendency to decrease from year to year. The carbonic acid too, which is characteristic of the ash of the non-Graminaceous part of the herbage, also diminishes somewhat from the first to the third year. On the other hand, the soda and the chlorine—constituents the most of all characteristic of crude and succulent growth—increase very obviously in their proportion in the ash from year to year.

Upon the whole then, these results, comparatively slight as the differences are, still indicate, as did those which have gone before, that there was a probable relative deficiency of *lime*, *potash*, and *silica*—especially of the latter two.

With regard to the results given in the fourth column attention may be called to the fact, that the figures represent the mean composition of the ash of specimens of hay grown under sixteen different manuring conditions, in each of the three widely differing seasons. The results may therefore be taken as showing the average mineral composition of the mixed herbage grown under a great variety of circumstances.

4.—*Nitrogen.*

For the information of the chemical reader it may be mentioned, that the *nitrogen* in the hay, as given in the Table, was determined by burning with soda-lime, and estimating by the volumetric method. Duplicate determinations were always made. The individual results are given for reference in Tables V., VI., and VII., in the Appendix. The *mean* results only, are given in Table XV. on the next page; and these will be in sufficient detail for the purpose of our illustrations. The *nitrogen* was thus determined, in the hay from every one of the experimental plots, in each of the three years of the experiments. The figures in the first set of four columns (Table XV.) represent the percentages of Nitrogen in the *fresh hay*—that is, in the condition in which it was carted from the land. The figures in the second Division represent the percentages in the *Dry substance of the hay.*

Plot, Nos.	MANURES (Per Acre, per Annum).	Percentages in the Hay as taken from the Land.				Percentages in the Dry Substance of the Hay.			
		1856.	1857.	1858.	Average of 3 years.	1856.	1857.	1858	Average of 3 years.
	SERIES 1.—Without Direct Mineral Manure.								
1	Unmanured	1·68	1·29	1·40	1·46	2·05	1·52	1·63	1·73
2	Unmanured (duplicate plot)	1·79	1·43	1·34	1·52	2·18	1·64	1·57	1·80
	Mean, or Standard Unmanured	1·73	1·36	1·37	1·49	2·11	1·58	1·60	1·76
3	2000 lbs. Sawdust	1·67	1·38	1·41	1·49	2·07	1·57	1·67	1·77
4	200 lbs. each, Sulphate and Muriate Ammonia	1·57	1·55	1·65	1·59	1·96	1·78	1·96	1·90
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·59	1·49	1·56	1·55	1·99	1·71	1·86	1·85
6	275 lbs. Nitrate of Soda	...	...	1·68	...	...	...	1·98	...
7	550 lbs. Nitrate of Soda	...	...	1·71	...	...	...	1·99	...
	Mean	1·64	1·44	1·56	1·55	2·03	1·66	1·84	1·84
	SERIES 2.—With Direct Mineral Manure.								
8	"Mixed Mineral Manure"*	1·67	1·51	1·40	1·53	2·09	1·74	1·64	1·82
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·77	1·48	1·39	1·55	2·21	1·71	1·65	1·86
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·23	1·18	1·25	1·22	1·55	1·36	1·53	1·48
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·26	1·11	1·17	1·18	1·64	1·27	1·40	1·44
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·47	1·33	1·35	1·38	1·85	1·55	1·64	1·68
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·49	1·62	1·71	1·61	1·88	1·88	2·12	1·96
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	...	1·53	...	...	...	1·76	...
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	1·32	...	...	...	1·55	...
	Mean	1·48	1·37	1·39	1·41	1·86	1·58	1·66	1·70
	SERIES 3.—With Farmyard Manure.								
16	14 Tons Farmyard Manure	1·35	1·31	1·18	1·28	1·77	1·50	1·40	1·56
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·62	1·08	1·27	1·32	2·04	1·26	1·53	1·61
	SUMMARY.								
	General Means for the Experimental Specimens	1·53	1·37	1·43	1·44	1·93	1·58	1·70	1·74
	Mixed Hay from the same Meadow, taken out of the rick December, 1858	...	1·33	1·16	...	...	1·53	1·39	...

* For full description of the "Mixed Mineral Manure," see page 6.

It will be found, that the percentage of *nitrogen* in the Dry substance of such heterogeneous and irregularly ripened produce as hay, is, like that of the mineral matter, contingent upon many coincident circumstances. Still, the results will show, as already alluded to, that, other things being equal, the lower the condition of maturation of the produce, the higher will be the percentage of Nitrogen, and *vice versâ*.

In accordance with this general observation, the Table shows that the season which gave the produce yielding the lowest average percentage of Dry substance, and the highest average percentage of Mineral matter in that dry substance (1856), gave also a produce containing a higher percentage of *nitrogen* in its dry substance than that of either of the years of higher condition of the hay. Conversely, the second season (1857), the produce of which showed the highest average percentage of dry matter, and the lowest average percentage of mineral matter in that dry substance, gave, at the time of cutting, a hay which contained the lowest average percentage of Nitrogen in that dry substance. As between the produce of one season with that of another, then, the general result was, that the more matured the condition of the hay, the lower was the percentage of Nitrogen in its dry substance. This is in general accordance with what we have elsewhere shown to obtain in the case of ripened crops—wheat and barley. It is true, that in the case of the hay-crop, the object is not a fully ripened produce. There is, therefore, of course, a limit below which a depreciation in the percentage of Nitrogen, the result of over-ripening, will be a disadvantage. At the same time, we believe that, comparing the produce of hay of one season with that of another, each cut at its proper stage of progress, that which has the lower percentage of Nitrogen in its dry substance will, taking the average of seasons, have its constituents in the better condition of elaboration, and be, therefore, a better food for animals.

The variations in the percentage of Nitrogen in the hay within one and the same season, according to the *manuring*, are very marked and interesting.

Taking the average result of the three seasons, the produce grown on the plot manured with ammonium-salts alone, contained a much higher percentage of Nitrogen in its dry substance than did that grown without manure. Again, the produce grown by ammonium-salts and sawdust gave a higher percentage of Nitrogen than that grown by sawdust alone. When the ammonium-salts were thus supplemented to the unmanured, or to the merely sawdusted conditions, the supply of Nitrogen was in considerable relative excess; as was shown by the greatly increased produce when the mixed mineral manure was superadded.

Under these circumstances, the percentage of the deficiently-provided Mineral constituents was comparatively low, whilst that of the relatively excessively supplied Nitrogen was considerably increased. The percentage of Nitrogen was thus increased, notwithstanding that the produce was almost entirely Graminaceous where the ammonium-salts were used; whilst, where they were not employed, it contained a notable proportion of Leguminous herbage, the percentage of Nitrogen in which is generally about twice as high as in purely Graminaceous produce. The high percentage of Nitrogen in the produce grown by ammonium-salts without mineral manure was, therefore, due to an increased percentage of it in the Graminaceous herbage. This highly nitrogenised Graminaceous produce consisted, it will be remembered, in very large proportion of *leaf;* it was stunted in growth; and was of a very dark green colour compared with the produce where there were larger crops.

The mixed mineral manure used alone, or in conjunction only with sawdust, gave a produce which contained a higher percentage of Nitrogen than either that grown without manure or with sawdust alone. The percentage of Nitrogen under these conditions was nearly as high as where the ammonium-salts, or the ammonium-salts and sawdust (without mineral manure), were used, which gave the stunted, dark green produce, above referred to. But the high percentage of Nitrogen in the produce now under consideration, namely, that grown by mineral without nitrogenous manure, was not due to a high percentage in the Graminaceous part of it. It was due to the fact, that the produce grown under these conditions contained a large proportion of Leguminous herbage, the percentage of Nitrogen in which is, as above stated, generally about twice as high as that in purely Graminaceous hay.

It has been seen, then, that the mineral manure alone gave a produce containing a high percentage of Nitrogen by increasing the proportion in it of the highly nitrogenous Leguminous herbage. It has also been seen, that the use of ammonium-salts alone, mineral constituents being in defect, gave a stunted Graminaceous produce, also with a considerably increased percentage of Nitrogen. The addition of ammonium-salts, when there was at the same time a liberal provision of mineral constituents, gave a very different result, both as to the character and amount of the crop, and as to the percentage of its Nitrogen.

If we compare the composition of the produce manured with both ammonium-salts and the mineral manure, with that grown by the mineral manure alone, or again, if we compare the produce by ammonium-salts, sawdust, and mineral manure, with that by the sawdust and mineral manure without the ammonium-

salts, the Table shows that, in both cases, the percentage of Nitrogen in the produce was considerably lower where the ammonium-salts were employed than in the comparable instances without them. This lower percentage of Nitrogen in the hay, by the addition of ammonium-salts to mineral manure, was partly due to the fact, that the produce grown by the mineral manure without the ammonium-salts, contained so large an amount of the highly Nitrogenous Leguminous herbage, whilst that grown with ammonium-salts in addition, was almost entirely Graminaceous. But the percentage of Nitrogen in this Graminaceous produce grown by ammonium-salts together with a liberal supply of mineral constituents, was also very much lower than that in the equally Graminaceous produce where the nitrogenous supply was in excess; that is to say, where the ammonium-salts were used without the mineral manure. Thus, taking the average of the three years, the percentage of Nitrogen in the dry substance of the hay grown by ammonium-salts alone, was 1·9; whilst that in the dry substance of the produce grown by the same amount of ammonium-salts, but in conjunction with the mineral manure, was only 1·48. This produce grown by the nitrogenous and mineral manure combined, was about 1⅘ time as great as that grown by the use of ammonium-salts alone; it was of a far lighter, and more lively green colour whilst growing; it was far more luxuriant; and it gave a much larger proportion of flowering and seeding stem. Such were the comparative characters of the produce, which contained much the lower percentage of Nitrogen. The higher percentage of Nitrogen in the produce grown by the ammonium-salts without the mineral manure was, therefore, coincident with a much smaller yield of hay, with a much less luxuriance of growth, and with a much larger proportion of leafy produce. In fact, in the case of hay, as in that of the ripened cereal grains, a relatively low percentage of Nitrogen (within certain limits) is, in cases comparable on the point, more likely to be associated with a relatively high, than with a relatively low condition, and degree of elaboration, of the constituents; and it is also more likely to be the result of moderately luxuriant, than of either stunted, or over-luxuriant growth.

The points last referred to, are aptly illustrated by a comparison of the characters, and nitrogenous percentage, of the hay grown by the double amount of ammonium-salts with the mineral manure, with those of the produce grown by the smaller amount of ammonium-salts and the same mineral manure. The average percentage of Nitrogen in the dry substance of the scarcely too heavy or luxuriant produce grown by the mineral manure and the smaller amount of ammonium-salts, was only 1·48; whilst, that in the dry substance of the over-luxuriant, unevenly-ripened

and laid and damaged produce, grown by the same mineral manure and the double or excessive amount of ammonium-salts, was 1·96. It will not be doubted, that the higher percentage of Nitrogen was, under these circumstances, coincident with a more crude and less favourable condition of the constituents of the hay. It has been shown experimentally by Professor Voelcker, that succulent plants may contain a part of their nitrogen in the condition of ammonium-salts; and Professor Sullivan has more recently called attention to the apparently frequent occurrence of both ammonia and nitric acid in the sap of plants. We had too, ourselves, long since pointed out, that turnips in which the percentage of Nitrogen was raised beyond a comparatively low amount by means of highly nitrogenous manures, were, weight for weight, of less feeding value than those having a far lower percentage of Nitrogen, but which were in a less crude and succulent, and a more highly elaborated condition. Indeed such highly nitrogenous turnips were even purgative and injurious.*

Attention should be called to the fact, that the produce grown by *nitrate of soda* alone, like that grown by ammonium-salts alone, contained a much higher percentage of Nitrogen, than that grown without manure.† Again, the addition of mineral manure to the nitrate of soda, by which the crop was considerably increased, gave a produce containing a lower percentage of Nitrogen than that grown by nitrate of soda alone.

Before leaving the results of Table XV., it may be observed that, *taking the average of the three seasons*, the addition of ammonium-salts to *farmyard manure*, gave a produce containing a slightly higher percentage of Nitrogen. In the second season, however, which was the one of the highest dryness and maturation of the hay, at the time of cutting, a contrary result was obtained.

From the whole of the results in regard to *nitrogen*, it would appear, that a *high percentage* is by no means a safe indication of relatively high feeding quality. In fact, in succulent and unripened produce more particularly, it is an uncertain indication even of high amount of elaborated nitrogenous vegetable compounds.

5.—*Cellular Matter, or Woody-Fibre.*

The constituent of vegetable food-stuffs, to which the term "*woody-fibre*" is frequently given, is that portion which remains undissolved after the application of such solvents as are supposed to remove all the other vegetable compounds—namely, the nitro-

* 'Jour. Roy. Agr. Soc. Eng.,' vol. x. (1849), pp. 306–315 inclusive.

† As the amount of nitrogen in the hay grown by the *nitrate of soda*, was determined by combustion with soda lime, and estimation as ammonia by the volumetric method, the high amount recorded in the Table could not be due to undecomposed nitric acid or nitrate.

genous substance, the fatty matter, the starch, the sugar, the gum, the extractive matters, &c. The substance so remaining generally retains, however, a certain amount of mineral matter, the quantity of which is determined by the incineration of the fibre. The attainment of certain results in regard to the amount of this so-called "woody-fibre" is, however, in practice, not a very easy matter. It is seldom that two experimenters have adopted the same methods for its quantitative estimation. And, although it is comparatively easy to determine whether or not the product of the process still retains some of the other matters enumerated above, it is by no means so easy to settle whether or not any portion of the substance which it is intended to include under the term Woody-fibre, has itself been rendered soluble and removed. For the results we have to lay before the reader under this head, as well as for those relating to the Fatty matter, to which we shall refer further on, we are indebted to M. Thomas Segelcke, of Copenhagen, who kindly undertook this part of the investigation whilst staying in the Rothamsted laboratory.

It would be out of place to go elaborately into the question of method here; and it is the less necessary as M. Segelcke has given a separate paper on the subject elsewhere.* It may be mentioned, however, that he in vain tried to get results which corresponded with one another when using the different methods that have been recommended. In fact, constancy of result seemed to be only attainable, when solvents of a constant strength were employed, for a fixed period of time, and at a given temperature. The necessity for observing fixed time and temperature, has been insisted upon by M. Millon; and the strength of solvents which M. Segelcke adopted in the analysis of the hays, as giving pretty uniform results, was very much the same as recommended by M. Peligot.

The method by which the results given in the Table were obtained, was briefly as follows:—about 10 grammes of the finely ground hay were first fully dried at a temperature of 212° F. The substance was next digested for three-quarters of an hour at a temperature, as nearly as it could be maintained, of 180° F., in 150 septems† of sulphuric acid, composed of one part, by volume, oil of vitriol, and two parts, by volume, water‡

* "On the Current Methods for estimating the Cellular matter, or 'Woody-fibre,' in Vegetable Food-stuffs;" see "Report of The British Association for the Advancement of Science, for 1859." Aberdeen Meeting; Section B.

† A septem measure is that of $\frac{1}{1000}$th of a pound avoirdupois, or 7 grains, of water.

‡ The above is the strength of acid recommended by M. Peligot. In subsequent investigation M. Segelcke has found, that results of which the duplicates were much more closely agreeing, and which still ranged very close to those recorded in the Table and obtained by the method described in the text, could be insured by using a weaker acid, but at a higher temperature. So far as his experiments have yet proceeded, the strength of acid which he has found to be the

After this digestion, the whole was diluted with hot water, filtered, and the insoluble matter well washed with hot water. At this stage the product retained several per cent. of nitrogenous substance, and a considerable amount of other matters which were dissolved in the next step of the process. The substance was removed from the filter, and then boiled for half an hour with 600 septems of very dilute caustic soda. The whole was again thrown on a filter and well washed with hot water. A drop of sulphuric acid was, however, added to the wash-water after the main portion of the washings had passed off; and the washing was continued until the water no longer came through acid. The matter was then washed from the filter, dried, and weighed as *woody fibre*. After this treatment, the product still retained 0·1 per cent., or less, of its weight of nitrogenous substance, and some mineral matter; both of which were determined and deducted by calculation.

The individual determinations of this Woody-fibre are given for reference in Table VIII. in the Appendix; and an examination of them will show within what limits the duplicate or triplicate results agree with one another. It is believed that the figures are probably very trustworthy as a comparative series, comparing specimen with specimen as to the respective amounts of Woody-fibre of a given degree of insolubility or induration; but they are pretty certainly too low considered as including the whole of the *cellulose*. At least M. Segelcke found that even Swedish filtering paper was somewhat reduced in amount by the second part of the process, namely, the treatment with the alkali after the acid, though it was not so by the digestion with either the acid or the alkali only. On the other hand, with any less treatment with the alkali, not only higher results, but inconstant duplicates or triplicates, were obtained; and the product at the same time retained a considerably higher amount of nitrogenous substance.

As already intimated, the *woody-fibre* was only determined in the hay of certain plots, namely, those selected for the botanical separations referred to in Part III. It was, however, determined in the produce of those plots, in each of the three years of the experiments. We are enabled, therefore, to trace the effects of both *season* and *manuring* on the percentage of the more insoluble *woody-fibre*—so far as it can be indicated by

best is, 1 volume of oil of vitriol to 16 volumes of water; the temperature that of the boiling point; and the time of action a quarter of an hour. A great practical advantage of substituting the use of a stronger acid, and a temperature below the boiling point, by a weaker acid and the boiling point, is the ease by which constancy in the latter temperature can be secured. Indeed, the discrepancies, such as they are, between the duplicate and triplicate determinations recorded in the Appendix, Table VIII., M. Segelcke attributes mainly to the accidental fluctuations in practice, somewhat above or below his then adopted temperature of 180° F.

the results of the method above described. The *means* only, of the two or more determinations made on each specimen, are given in Table XVI. which now follows; and it is these to which we shall confine attention.

The professed object of determining the amount of *woody-fibre* in our food-stuffs, is to acquire some means of judging of their amount of probably indigestible and effete material. Now, it is sufficiently apparent from the researches of many able investigators, among whom we may mention Mulder, Harting, Boussingault, Millon, Peligot, Mitcherlich, Chevreul, Fremy, Cramer, and Payen, that the substance to which is given the somewhat generic term *woody-fibre*, comprises many modifications, which vary from each other, in physical characters, and in behaviour to solvents, according to age, and other circumstances of their deposition, and to the character and amount of the incrusting matters, and of the injected or foreign matters with which they are associated. In fact, some of the modifications which yield most easily to certain chemical solvents, seem to be separated by almost imperceptible lines of demarcation, from the admittedly more digestible starchy bodies. The two series of bodies appear, indeed, to be mutually transformable, not only in the laboratory of vegetable existence, but more or less in that of the chemist also.

How then, are we by the chemical analysis of a food, to determine exactly at what point of aggregation, induration, or protection by foreign substances, its Cellular or Woody matter is to be accounted as indigestible, innutritious, and effete? So long as the Cellular substance is in such a condition as to be easily acted upon by chemical solvents, or to be transformable within the plant, we may perhaps venture to assume, that it would not be wholly refractory to the digestive agencies of animals. If, therefore, it be admitted, that the amounts of matter recorded as *woody-fibre* in our Table, do not include the more delicate and changeable Cellulose of the vegetable substance examined, they may, nevertheless, on that account, the more nearly represent the proportions of the respective hays, that will be necessarily indigestible and effete. In fact, although we do not at all claim that the results do indicate the *total Cellulose* of the specimens examined, we still believe, that, so far as present experience goes, results so obtained are the best means at command for the purpose of comparing the specimens one with another, in regard to the relative proportion in each of the more refractory Cellular matter. And, so far as the substance which resists the action of solvents employed in the degree above described, may be found to be really indigestible and effete, a large relative proportion would, in this point of view, be objectionable. At the same

Plot, Nos.	(Per Acre, per Annum.)	1856.	1857.	1858.	of 3 Years.
	Percentages in the Hay as taken from the Land.				
1	Unmanured	24·5	22·9	22·9	23·4
4	200 lbs. each, Sulphate and Muriate Ammonia	24·8	23·1	22·9	23·6
8	"Mixed Mineral Manure" *	24·0	23·0	25·0	24 0
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·5	25·3	24·1	25·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	25·6	24·2	23·6	24·5
16	14 tons Farm-yard Manure	23·7	25·8	24·5	24·7
17	14 tons Farm-yard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	23·6	25·0	24·3	24·3
	Means	24·5	24·2	23·9	24·2
	Percentages in the Dry Substances of the Hay.				
1	Unmanured	29·9	26·9	26·6	27·8
4	200 lbs. each, Sulphate and Muriate Ammonia	31·0	26·6	27·2	28·3
8	"Mixed Mineral Manure"	30·0	26·5	29·2	28·6
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	32·3	29·0	29·4	30·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	32·8	28 2	29·3	30·1
16	14 tons Farm-yard Manure	31·2	29·6	29·0	29·9
17	14 tons Farm-yard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	29·7	29·0	29·4	29·4
	Means	31·0	28·0	28·7	29·2

* For full description of the "Mixed Mineral Manure," see page 6.

time, it must be borne in mind, that a certain proportion of this otherwise useless and effete matter, is absolutely essential to give bulk, and to aid the digestion of the other constituents of the food, especially of our ruminant animals.

With these brief observations on the character, and the relationships, of the substance the amounts of which, in the respective hays, are recorded in the Table, attention may now be directed to the results there given.

In the upper portion of Table XVI., the percentages of *woody-fibre*, or more properly of comparatively indurated Cellular matter, in the *fresh hay* are given; and in the lower Division, the percentages in the *Dry substance* of the hay. The latter indicate the most clearly the differences in the composition of the vegetable substance of the hay. Comparing the produce of one season with that of another, the percentage of this comparatively insoluble Woody-fibre is, on the average, considerably the highest in that of the wet, cold, and ungenial season 1856, and the lowest in that of 1857. It will be remembered that the produce of 1856, which shows the largest proportion of comparatively refractory Woody matter in its Dry substance, gave a very low percentage of Dry substance; but high percentages of both Mineral matter, and Nitrogen (in a questionable degree of elaboration), in that Dry substance. And, conversely, the produce of 1857, which now gives the lowest proportion of such Woody-fibre in its Dry substance, gave the highest proportion of Dry substance, and the lowest proportion of Mineral matter, and of Nitrogen, in that Dry substance.

It might perhaps not have been anticipated, that the season which gave the most crude, succulent, and ill-conditioned produce, would at the same time give a vegetable substance containing a high proportion of comparatively indurated Cellular or Woody matter. In all cases, the specimens were so far dried soon after they were collected, as to leave in them only about 5 per cent., or less, of moisture; and in this condition they were ground and preserved. And, as the Woody-fibre determinations have only recently been made, the produce of 1856 has had some considerable time for change, were it liable to it. Under the circumstances of the preparation and preservation of the specimens, however, it would be difficult to conceive of any changes that would raise the percentage of indurated Cellular matter in the remaining substance, to the extent indicated in the Table above that in the produce of the other years. Against the probability of such change, may be noted the fact, that the produce of 1857, which had been preserved for nearly 2 years when examined, gave a *lower* percentage of this Woody-fibre in its Dry substance, than that of 1858 which, of course, had not been preserved so long. On the

other hand, neither do any of our records as to the character of the produce in the several years, or as to the characters of the seasons themselves, lead to the belief that the produce of 1856 was either in such large proportion *stemmy*, or so *forward*, at the time of cutting, as that of the other seasons. Should then, future researches confirm the indications of these results, we should have to adopt the important conclusion, that a crude and succulent produce—a large proportion of whose more soluble constituents exists in a low condition of elaboration—may at the same time have a large proportion of its more fixed constituents in the condition of comparatively indurated and innutritious Cellular matter. Or, may it be, that, when there is a low condition of elaboration of some of the more soluble constituents, so large a proportion of these undergo change, as to leave the more fixed Woody matter in larger proportion in the remaining total dry substance?

When the observed variations in the character of the produce are borne in mind, the effects of *manures* upon the relative percentages of the more fixed Woody-fibre in its Dry substance, are more clearly in accordance with what would be expected than are those of *season*. Taking the average result of the 3 years, the Dry substance of the *unmanured* produce, contained a comparatively low percentage of such Woody-fibre. This produce contained a large proportion of non-Graminaceous herbage; a fair proportion was stemmy, but it was backward; and with these characters there is a low percentage of Woody-fibre in the Dry substance. The Dry substance of the produce by *ammonium-salts alone*, whose Graminaceous stems were comparatively ripe, but which contained a very large proportion of leaf, contained at the same time a comparatively small proportion of the "woody-fibre." The produce by *Mineral manures alone*, consisted of a good deal of non-Graminaceous herbage, and the Graminaceous herbage comprised a considerable proportion of leaf, though its stems were comparatively ripe. With these characters, the percentage of the "woody-fibre" in the Dry substance was comparatively low. Where the *mixed mineral manure and ammonium-salts were used together*, the produce was, comparatively, somewhat unripe; but it was almost entirely Graminaceous, and in very large proportion stemmy, and coincidently there is a comparatively large proportion of the "woody-fibre" in the Dry substance. The produce by *farm-yard manure* was in a still larger proportion stemmy; but it contained also a considerable proportion of non-Graminaceous herbage. The result was, that its Dry substance contained a comparatively high percentage of the "woody-fibre," but not quite so high as that where the mineral manure and ammonium-salts were used, and the produce was more exclusively Graminaceous.

Adopting the experimental indications which have been recorded, as the most trustworthy which, in the existing condition of our knowledge on the points in question, could be supplied, the result upon the whole would appear to be, that, on the one hand, a generally low condition of elaboration of succulent produce may still be associated with a high proportion of comparatively indurated, and therefore probably innutritious Cellular matter, in its dry substance. On the other hand, comparing the produce by different *manures*, in one and the same season, the more Graminaceous, the more stemmy, and the riper, the higher will be the proportion of the comparatively indurated Woody or Cellular matter.

6.—*Fatty Matter.*

In the analysis of animal and vegetable food-stuffs, it is usual to estimate as "*Fatty Matter*," that portion which is dissolved out from the dried substance by means of Ether. In the case of animal substances, or of ripened vegetable ones, such as grain, the substance so determined does generally represent a fatty matter of high respiratory and fat-forming capacity. Not so, however, in the case of crude, unripened, vegetable produce. In fact, in such produce, the so-called *fatty matter*, separated merely by extraction with ether, is largely contaminated with waxy and green colouring matter, a considerable proportion of which passes from the animal in its solid excrements. A relatively large proportion of such impure fatty substance can hardly be regarded, therefore, as an advantage. Still, it is useful to ascertain the amount of such matter, if it be only that, by a careful consideration of the conditions of growth, and other admitted qualities of the hay yielding the larger or the smaller proportions of it, we may be the better able to form a valid decision, whether or not the substance in question is likely really to indicate the high condition of elaboration of the constituents, which a large proportion of *pure fatty matter* might be supposed to do. A further reason for determining the amount of this substance, notwithstanding that we consider it of such doubtful value, is the fact, that this mode of analysis has been adopted with apparent confidence by most of our predecessors; whilst an accurate separation of the several bodies which compose this Ether-extract, would have increased the labour of analysis beyond that which it was practicable to devote to it. Nor, is the quantity of this impure Fatty matter in hay so large, as to render the differences in its amount of much importance in any other point of view, than as indicating the general character and condition of the produce.

The method adopted by M. Segelcke, in his determinations

e *crude fatty matter*, was to pass ether through a dried and ıed portion of the finely ground hay, until it came through rless. For this purpose, he devised an apparatus, by means ich the ether was continuously distilled from the extract, epassed through the substance. At the end of the first nent in this way, that is, when the ether passed through rless, the substance was re-dried in the water bath, and submitted to a second extraction in the ether-apparatus. ther was finally distilled from the total ether-extract; and emaining *green fatty matter* was dried in a water bath, until longer lost weight.

om what has already been said of the character of the "Fatty er," the quantity of which in the respective hays, was deter-d by the methods just described, it would be useless to go much detail as to the amounts found in the different speci-. It is the less desirable, too, to do so, as the circumstances xtent of its occurrence will be sufficiently brought to light, king the summary view of the composition of the different with which we now propose to conclude our Report. The idual determinations of the Fatty matter will be found in e IX. in the Appendix; and the mean percentages of it are died with those of the other constituents in Table XVII., ich attention is next, and lastly, to be directed.

7.—*Summary of the Composition of the Hay.*

Table XVII. is given a summary view of the collective osition of the specimens of hay grown in the Third Season 8), on those plots the produce of which was selected for the ical separations. In the upper Division of the Table, the entages of the several constituents *in the fresh hay as carted the land*, are given. In the middle Division, the percentages ıe *Dry substance* of the hay are given. And in the lowest sion, is a summary statement of the general description of herbage on the respective plots. The means are thus ded, of considering the chemical composition of the re-tive hays, in connection with the other known characters of herbage. The constituents given are:—

1st. Nitrogenous substance.
2nd. Fatty matter.
3rd. Woody-fibre.
4th. Other non-nitrogenous vegetable compounds.
5th. Mineral matter.
6th. Total Dry substance.
7th. Water.

A few brief remarks should first be made, as to the character of the several substances represented in the above enumeration.

Nitrogenous substance.—The most practicable and usual mode of getting at an approximate estimate of the total amount of Nitrogenous compounds, in vegetable or animal food-stuffs, is to determine the amount of *nitrogen*, and calculate from it the amount of Nitrogenous substances, on the assumption that they consist of the so-called *proteine compounds*. Adopting this assumption, the amount of Nitrogen has only to be multiplied by 6·3, to give, very nearly, the amount of Nitrogenous proximates that it would represent. This is the method which, from convenience, we have adopted. From what has been said under the head of Nitrogen, however, it will be obvious, that this mode of estimation affords, more particularly in the case of succulent and unripened produce, at best but an uncertain indication of the amount of elaborated and nutritive Nitrogenous compound. The so-calculated Nitrogenous substance may, in fact, not only include a quantity of matter in a low condition of elaboration, but even ammonium-salts. It will be understood, therefore, with what degree of reservation the recorded amounts of "*nitrogenous substance*" must be taken, as indicating the probable amounts of nutritive proteine compounds.

Fatty matter.—The substance given under the head of Fatty matter, includes, as has been already explained, a quantity of waxy and green colouring matter, and must not be taken, therefore, as representing pure Fatty matter of high respiratory and fat-forming capacity.

Woody-fibre.—It will be borne in mind, that the substance recorded as Woody-fibre, is not supposed to include the whole of the Cellular matter in its various modifications; but only that amount of it which seems to possess a certain fixed degree of persistence, on the application of such solvents as are required to remove the other compounds. It is possible, however, that at any rate the easily changeable, and easily dissolved portions of the Cellular substance, may be amenable to the digestive organs of animals.

Other non-nitrogenous matters.—The substances put down as *other non-nitrogenous matters*, are all those which remain after deducting the "Nitrogenous substance," the "Fatty matter," and the "Woody-fibre," as above defined, and also the "Mineral matter." They comprise probably starch, dextrine, gum, sugar, and certain extractive matters. They will also include so much of the more easily changeable Cellular substance, as may have been dissolved by the re-agents required to remove all the other matters, in the process adopted for separating and estimating that portion which is recorded as "Woody-fibre." The characters, and

CONSTITUENTS.	HAY FROM SELECTED EXPERIMENTAL PLOTS.								
		Artificial Manures.				Farmyard Manure.		Mean.	Mixed Hay from same Meadow: cut out of rick December, 1858.
	Unmanured. (Plot 1.)	Ammonium-salts, alone. (Plot 4.)	"Mixed Mineral Manure." (Plot 8.)	"Mixed Mineral Manure" and Ammonium-salts. (Plot 10.)	"Mixed Mineral Manure" and double quantity Ammonium-salts. (Plot 13.)	Alone. (Plot 16.)	With Ammonium-salts. (Plot 17.)		
1.—Composition per Cent. in the Fresh Hay.									
Nitrogenous Substance (N.×6·3, reckoning 15·875 N. in Nit. Sub.)	8·82	10·39	8·83	7·87	10·77	7·43	8·00	8·87	...
Fatty Matter (Ether Extract)	2·87	3·00	2·55	1·99	2·36	2·48	2·80	2·58	...
Woody-fibre	22·88	22·87	24·97	24·11	23·64	24·51	24·31	23·90	...
Other non-Nitrogenous Vegetable Compounds (Starch, Sugar, Gum, &c.)	45·63	42·70	42·78	41·60	37·58	43·46	40·85	42·08	...
Mineral Matter (Ash)	5·70	5·14	6·48	6·53	6·35	6·72	6·74	6·24	5·73
Total Dry Substance	85·90	84·10	85·60	82·10	80·70	84·60	82·70	83·67	83·80
Water	14·10	15·90	14·40	17·19	19·30	15·40	17·30	16·33	...
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	...
2.—Composition per Cent. in the Dry Substance of the Hay									
Nitrogenous Substance (N.×6·3, reckoning 15·875 N. in Nit. Sub.)	10·27	12·35	10·33	9·58	13·36	8·82	9·64	10·62	...
Fatty Matter (Ether Extract)	3·34	3·57	2·98	2·42	2·93	2·93	3·39	3·08	...
Woody-fibre	26·63	27·20	29·17	29·37	29·30	28·97	29·40	28·58	...
Other non-Nitrogenous Vegetable Compounds (Starch, Sugar, Gum, &c.)	53·12	50·77	49·95	50·68	46·54	51·33	49·43	50·27	...
Mineral Matter (Ash)	6·64	6·11	7·57	7·95	7·87	7·95	8·14	7·45	6·84
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	...
3.—Summary Statement of the Description of the Herbage.									
Graminaceous Stems bearing Flower or Seed	50·25	35·91	42·18	72·66	65·08	60·76	64·62	57·21	...
Graminaceous Leafy Produce	25·85	53·20	29·64	24·72	32·27	17·91	15·05	28·38	...
Leguminous Herbage	5·12	2·20	22·89	...	...	3·70	1·78	5·10	...
Miscellaneous Herbage (chiefly weeds)	15·73	6·14	1·71	1·85	1·67	7·05	16·43	7·23	...
Shedded Seeds, and Indeterminate Vegetable Matter	3·05	2·55	3·58	0·77	0·98	1·58	2·12	2·08	...
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	...

the feeding capacity, of the substances grouped together under this head of *other non-nitrogenous matters*, will probably depend much upon the *condition* of the hay. The worse the condition of the hay, the greater probably will be the proportion of them, which will consist of the ill-defined "extractive matters."

Mineral matter.—The so-designated Mineral matter, is that which remains as *ash*, on the incineration of the hay. It is needless to say that Mineral constituents are essential in the food of animals. In most vegetable foods, however, they generally exist in a larger proportion to the other constituents than they are probably required; and hence their large amount in any food is no criterion of high feeding value. On the contrary, as, in comparable cases, a high percentage of Mineral matter is generally coincident with a low degree of elaboration of the collateral vegetable substances, the smaller percentage among a series of specimens of produce of like description, will most probably be associated with a higher relative feeding capacity.

The proportions of these several constituents, in the hay grown by the different manures, may now be briefly noticed.

The *unmanured* hay contained a notable proportion of Leguminous, and other non-Graminaceous herbage; and the Grasses themselves were stunted. Under these circumstances, the Dry substance of the hay contained a medium percentage of the calculated Nitrogenous compounds, and comparatively a very small proportion of the estimated Woody-fibre. Comparing the produce of one manuring condition with that of another, in one and the same season, a low percentage of indurated Woody-fibre indicates greenness and immaturity. Coincidently with this, the unmanured hay shows a relatively high amount of the impure Fatty matter.

The produce grown by *ammonium-salts alone*, contained a very high percentage of Nitrogenous compounds, or at least of Nitrogen in some form. This was due, it will be remembered, not to a large amount of Leguminous herbage, but to the condition of the almost exclusively Graminaceous hay, which was stunted, dark green, leafy, and backward. The Dry substance of the hay having these characters, at the same time contained only a small proportion of the comparatively stable Cellular or Woody matter; but it had the highest amount of any in the series of the green impure Fatty matter. The fact, that the highest percentage of this merely ether-extracted substance, was found in this stunted, dark-green, leafy, and backward produce, may perhaps be taken as some indication, that a relatively high amount of Fatty matter as so determined, in succulent produce, does not really represent a high amount of *pure fat* of the high feeding capacity which that substance is assumed to possess.

The produce by *mineral manure alone*, which contained the *highest* proportion of any, of Leguminous herbage, nevertheless

contained but a moderate percentage of Nitrogenous compounds. This arose from the fact, that the *grasses*, which still constituted by far the largest proportion of the produce, though meagre and stunted in growth, were still comparatively forward. With these characters, the percentage of the so-called Woody-fibre is comparatively high, and that of the impure Fatty matter is comparatively low.

The produce of the plot manured with the *mineral manure and the smaller amount of ammonium-salts* was bulky, almost wholly Graminaceous, and very stemmy. Consistently, the dry substance of this hay contained a low proportion of Nitrogenous compounds, the lowest amount of any in the series of the green Fatty matter, and a high percentage of the more fixed Cellular substance.

The *mineral manure* together with the *double and excessive amount of ammonium-salts*, gave an over-luxuriant, succulent, and unevenly ripened, but stemmy and almost exclusively Graminaceous produce. To the former characters may be attributed a very high percentage of the calculated Nitrogenous compounds; and to the latter a somewhat low percentage of the impure Fatty matter, and a high one of the Woody-fibre. The percentage of the green Fatty matter is, however, as would be expected, higher than in the produce grown by the mineral manure and the smaller amount of ammonium-salts. The remainder, designated as "other non-nitrogeneous matters," is less in this over-luxuriant produce than in any of the other cases.

The produce by *farm-yard manure alone*, comprised a moderate proportion of Leguminous and other non-Graminaceous herbage; but, on the other hand, its Graminaceous herbage was in very large proportion in the condition of flowering and seeding stem. Consequently, the Dry substance of the hay contained a low percentage of the Nitrogenous compounds, a low percentage of the impure Fatty matter, and a high percentage of the Woody-fibre.

The hay grown by *farm-yard manure and ammonium-salts together*, comprised a larger proportion of non-Graminaceous herbage, than that grown by farm-yard manure alone; but, the Graminaceous herbage itself was in as great a proportion stemmy. The result was a hay containing in its dry substance, a considerably higher proportion both of the calculated Nitrogenous compounds and of the impure Fatty matter, and at the same time a high percentage of the Woody-fibre.

The general result, comparing the produce by the different manures in one and the same season, seems to be, that the more the produce is Graminaceous, the more it goes to flower and seed, and the more it is ripened, the higher will be the percentage of *dry substance* in the hay. Under the same circumstances, the higher will be the percentage of the *comparatively* indurated, and therefore *probably effete*, Cellular matter or "Woody-fibre;" and

the lower will be that of the *calculated nitrogenous compounds*, of the *impure green fatty matter*, and of the *mineral matter* in the Dry substance. On the other hand, a large proportion of the non-Graminaceous herbage, over-luxuriance, succulence, a large proportion of leaf, and unripeness, are likely to be associated with a small proportion of the *more refractory or effete, Cellular or Woody-matter*, but with a large one of *nitrogenous substance in a questionable degree of elaboration*, a large one of *impure fatty matter* of doubtful nutritive capacity, and a large one of the *mineral matter* also, in the Dry substance of the hay.

This subject obviously throws open a wide field for future investigation. And, if we consider, not only the very complex character, in so many points of view, of the substance included under the term—*hay*, but also the inadequacy of the data, although so copious, which we have collected and recorded in the course of our long Paper, it will be at once apparent, that it would be inconsistent with a proper spirit of inquiry, to attempt to do more than draw attention to the prominent indications, and leading directions, of the experimental evidence that has been adduced. There will, nevertheless, be much really gained, if a clear idea be conveyed of the multiplicity of circumstances, upon which must depend the proportion, and relative feeding value, of the various chemical compounds of which the complex produce is made up. It will, then, be understood—and it is very important that it should be—that even supposing there were no question as to the proper relationship to one another, of the different elaborated compounds in our stock-foods, it would still be impracticable to get a true and unconditional estimate of comparative feeding value of *crude vegetable substances*, by the simple determination of the percentage amount of one or two important constituents, as is frequently assumed to be sufficient for that purpose. The next step in advance in these inquiries can only be attained, when our knowledge of the proximate compounds, of lower or of higher condition of elaboration, into which the ultimate constituents of our food-stuffs are grouped, has been much extended, and when the digestibility, and applicability to the purposes of the system, of these various proximate compounds, have been experimentally determined.

[For the general conclusions in regard to the other separate Sections of the subject into which our Report has been divided, see concluding portions of Parts I., II., and III., at pages 22-4, 41-2, and 67-8, respectively.]

Plot, Nos.	MANURES, (Per Acre, per Annum.)	Season 1856.		Season 1857.		Season 1858.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.						
1	Unmanured	82·1	81·8	85·0	85·3	86·0	85·9
2	Unmanured (duplicate plot)	81·6	82·2	87·3	87·3	85·8	85·1
	Calculated Means of Unmanured	81·8	82·0	86·1	86·3	85·9	85·5
3	2000 lbs. Sawdust	80·6	80·8	87·9	87·5	84·2	84·6
4	200 lbs. each, Sulphate and Muriate Ammonia	79·0	81·0	87·2	86·1	84·0	84·2
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	79·8	79·5	87·7	87·6	84·0	83·8
6	275 lbs. Nitrate of Soda	...	...	...	...	84·6	85·0
7	550 lbs. Nitrate of Soda	...	...	...	...	85·7	86·0
	SERIES 2.—With Direct Mineral Manure.						
8	"Mixed Mineral Manure" *	80·5	80·0	86·8	86·7	85·6	85·6
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	80·6	80·4	86·8	86·8	84·0	84·2
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	78·9	79·0	87·1	87·0	82·0	82·2
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	77·8	76·8	87·6	86·8	83·9	83·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·4	79·0	86·5	87·1	82·4	82·4
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	77·8	78·4	86·1	85·8	80·2	81·1
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	...	...	...	...	86·1	86·7
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	...	...	...	...	85·4	85·0
	SERIES 3.—With Farmyard Manure.						
16	14 Tons Farmyard Manure	76·0	76·2	87·4	87·3	85·0	84·2
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	79·5	79·6	86·4	86·1	82·4	83·0

* For full description of the "Mixed Mineral Manure," see page 6.

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table II.—Duplicate Determinations of Mineral Matter (Ash), in the Hay of the Season 1856.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	6·25	6·27	7·61	7·66
2	Unmanured (duplicate plot)	6·60	6·68	8·09	8·12
	Calculated Means of Unmanured	6·42	6·48	7·85	7·89
3	2000 lbs. Sawdust	6·60	6·64	8·19	8·21
4	200 lbs. each, Sulphate and Muriate Ammonia	6·75	6·13	8·55	7·56
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·95	6·06	7·47	7·62
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·94	6·91	8·62	8·64
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	7·39	7·23	9·18	8·99
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·64	6·91	8·42	8·74
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	7·23	6·83	9·29	8·90
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·78	6·67	8·54	8·44
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·74	6·40	8·66	8·16
	Series. 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	7·30	7·29	9·59	9·56
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	8·66†	6·38†	10·88†	8·01†

* For full description of the "Mixed Mineral Manure," see page 6.

† There is obviously some error in these determinations; whether due to the accidental mixture with one another of a portion of the duplicate quantities, or to adventitious matter in the case of the higher number, is doubtful. It will be easily understood, that in such complex and uneven produce as hay, the determinations of both Dry matter, and Mineral matter, will be more liable to uncertainty than in that of grain, and other comparatively uniform produce.

APPENDIX.—Table III.—Duplicate Determinations of Mineral Matter (Ash), in the Hay of the Season 1857.

Plot, No.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	5·58	5·68	6·56	6·66
2	Unmanured (duplicate plot)	5·71	5·71	6·54	6·54
	Calculated Means of Unmanured	5·65	5·69	6·55	6·60
3	2000 lbs. Sawdust	5·60	5·68	6·37	6·49
4	200 lbs. each, Sulphate and Muriate Ammonia	5·52	5.44	6·33	6·31
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·55	5·47	6·33	6·25
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·00	6·32	6·91	7·29
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	6·83	6·36	7·87	7·33
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·32	6·24	7·26	7·17
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·43	6·40	7·34	7·37
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·78	6·67	8·54	8·44
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·49	6·35	7·53	7·40
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	6·46	6·56	7·39	7·52
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	6·48	6·42	7·50	7·46

* For full description of the "Mixed Mineral Manure," see page 6.

EXPERIMENTS with DIFFERENT MANURES on PERMANENT MEADOW LAND.

APPENDIX.—TABLE IV.—Duplicate Determinations of MINERAL MATTER (Ash), in the Hay of the Season 1858.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	5·73	5·68	6·66	6·61
2	Unmanured (duplicate plot)	5·56	5·56	6·48	6·53
	Calculated Means of Unmanured	5·64	5·62	6·57	6·57
3	2000 lbs. Saw dus	5·60	5·62	6·65	6·64
4	200 lbs. each, Sulphate and Muriate Ammonia	5·39	4·88	6·42	5·80
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·34	5·32	6·36	6·34
6	275 lbs. Nitrate of Soda	5·80	5·66	6·85	6·66
7	550 lbs. Nitrate of Soda	5·37	5·39	6·26	6·27
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·48	6·48	7·57	7·57
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	6·48	6·46	7·71	7·68
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia ...	6·53	6·54	7·96	7·95
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·96	6·64	8·30	7·92
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·69	6·67	8·12	8·10
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia ...	6·32	6·38	7·88	7·86
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	6·37	6·43	7·39	7·42
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	6·38	6·66	7·47	7·83
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	6·73	6·71	7·92	7·97
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia ...	6·72	6·75	8·15	8·13

* For full description of the "Mixed Mineral Manure," see page 6.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Nitrogen taken from the Land.		Nitrogen Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	1·70	1·66	2·07	2·03
2	Unmanured (duplicate plot)	1·79	1·79	2·19	2·18
	Calculated Means of Unmanured	1·74	1·72	2·13	2·10
3	2000 lbs. Sawdust	1·69	1·66	2·09	2·06
4	200 lbs. each, Sulphate and Muriate Ammonia	1·57	1·57	1·96	1·96
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·56	1·62	1·96	2·03
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	1·67	1·68	2·08	2·10
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·80	1·75	2·24	2·18
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·22	1·24	1·54	1·57
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·28	1·25	1·66	1·62
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·48	1·46	1·86	1·85
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·49	1·49	1·88	1·88
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·35	1·35	1·77	1·78
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·65	1·60	2·07	2·01

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table VI.—Duplicate Determinations of Nitrogen, in the Hay of the Season 1857.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	1·29	1·29	1·52	1·52
2	Unmanured (duplicate plot)	1·42	1·45	1·63	1·66
	Calculated Means of Unmanured	1·35	1·37	1·57	1·59
3	2000 lbs. Sawdust	1·38	1·38	1·57	1·57
4	200 lbs. each, Sulphate and Muriate Ammonia	1·59	1·51	1·83	1·74
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·54	1·45	1·76	1·66
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure" *	1·51	1·51	1·74	1·74
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·49	1·48	1·72	1·71
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·19	1·18	1·37	1·36
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·12	1·10	1·29	1·26
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·38	1·29	1·60	1·51
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·62	1·62	1·89	1·88
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·29	1·33	1·48	1·52
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·07	1·10	1·24	1·28

* For full description of the "Mixed Mineral Manure," see page 6.

APPENDIX.—TABLE VII.—Duplicate Determinations of NITROGEN, in the Hay of the Season 1856.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	1·39	1·42	1·62	1·65
2	Unmanured (duplicate plot)	1·35	1·34	1·58	1·57
	Calculated Means of Unmanured...	1·37	1·38	1·60	1·61
3	2000 lbs. Sawdust	1·41	1·42	1·67	1·68
4	200 lbs. each, Sulphate and Muriate Ammonia	1·69	1·61	2·01	1·92
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·56	1·56	1·86	1·86
6	275 lbs. Nitrate of Soda	1·67	1·69	1·97	1·99
7	550 lbs. Nitrate of Soda	1·71	1·71	1·99	1·99
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure" *	1·39	1·42	1·63	1·66
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·39	1·39	1·65	1·65
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia ...	1·25	1·26	1·52	1·53
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·18	1·17	1·41	1·40
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·34	1·36	1·63	1·65
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia ...	1·70	1·72	2·11	2·13
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	1·52	1·52	1·76	1·76
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	1·31	1·34	1·54	1·57
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·18	1·18	1·40	1·40
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia ...	1·29	1·25	1·56	1·51

* For full description of the "Mixed Mineral Manure," see page 6.

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table VIII.—Individual Determinations of Woody-fibre, in the Hay from Selected Plots; Seasons 1856, 1857, and 1858

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.			Percentages in the Dry Substance of the Hay.		
		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 1.	Experiment 2.	Experiment 3.
	Season 1856.						
1	Unmanured	24·76	24·27	...	30·2	29·6	...
4	200 lbs. each, Sulphate and Muriate Ammonia	24·96	24·72	...	31·2	30·9	...
8	"Mixed Mineral Manure"*	23·98	24·14	...	29·9	30·1	...
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·52	25·52	...	32·3	32·3	...
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	25·85	25·38	...	33·1	32·5	...
16	14 Tons Farmyard Manure	24·12	23·44	...	31·7	30·8	...
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	23·56	23·72	...	29·6	29·8	...
	Season 1857.						
1	Unmanured	23·32	23·15	22·11	27·4	27·2	26·1
4	200 lbs each, Sulphate and Muriate Ammonia	22·89	23·41	22·89	26·4	27·0	26·4
8	"Mixed Mineral Manure"	23·06	23·06	22·89	26·6	26·6	26·4
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·40	24·97	25·40	29·2	28·7	29·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	24·14	24·57	23·79	28·1	28·6	27·7
16	14 Tons Farmyard Manure	26·19	26·19	25·14	30·0	30·0	28·8
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	24·57	24·91	25·43	28·5	28·9	29·5
	Season 1858.						
1	Unmanured	22·68	22·68	23·28	26·4	26·4	27·1
4	200 lbs. each, Sulphate and Muriate Ammonia	22·54	22·96	23 13	26·8	27·3	27·5
8	"Mixed Mineral Manure"	25·08	24·65	25·17	29·3	28·8	29·4
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	24·05	24·55	23·73	29·3	29·9	28·9
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	23·24	23·32	24·37	28·8	28·9	30·2

APPENDIX.—Table IX.—Duplicate Determinations of Fatty Matter (by Ether), in the Hay from Selected Plots (Season 1858).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Experiment 1.	Experiment 2.	Mean.
	Percentages in the Hay as taken from the Land.			
1	Unmanured	2·87	2·86	2·86
4	200 lbs. each, Sulphate and Muriate Ammonia	3·04	2·96	3·00
8	"Mixed Mineral Manure" *	2·58	2·52	2·55
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2·04	1·93	1·99
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	2·43	2·29	2·36
16	14 Tons Farmyard Manure	2·49	2·46	2·47
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	2·81	2·79	2·80
	Percentages in the Dry Substance of the Hay.			
1	Unmanured	3·34	3·33	3·34
4	200 lbs. each, Sulphate and Muriate Ammonia	3·61	3·52	3·57
8	"Mixed Mineral Manure"	3·01	2·94	2·98
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2·49	2·35	2·42
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	3·01	2·84	2·93
16	14 Tons Farmyard Manure	2·94	2·91	2·93
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	3·40	3·38	3·39

* For full description of the "Mixed Mineral Manure," see page 6.

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REPORT OF EXPERIMENTS

ON THE

GROWTH OF RED CLOVER

BY

DIFFERENT MANURES.

BY

J. B. LAWES, F.R.S., F.C.S., & DR. J. H. GILBERT, F.R.S., F.C.S.

PART I.

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[Diagram to face page 11.]

EPORT OF EXPERIMENTS ON THE GROWTH OF RED CLOVER BY DIFFERENT MANURES.

Part I.

:w questions in connexion with agriculture have excited more ention, or have been the subject of a greater variety of ex- inations, than the failure of Red Clover. It certainly seems newhat strange that, whilst some of our farm crops can be)wn year after year, or in pretty close succession, on the same id for a considerable period of time, and, for what we yet ow to the contrary, continuously, others will only succeed when ne years have elapsed since the same description of crop was)wn.

In works on agriculture the failure of Clover is accounted for a great number of ways, among which the following assumed ises may be mentioned:—

Exhaustion of the soil;

The growth of parasitic plants, which strike their roots into the clover and exhaust its juices;

Destruction by insects;

The injurious influences arising from the matter excreted by the roots of the former crop, or from the decay of the roots themselves;

The growth of the young plant under the shade of a corn crop.

Although the Clover crop may be found to suffer from more an one of the above-enumerated causes, the phenomena which esent themselves are nevertheless by no means satisfactorily plained; and, so far as prevention is concerned, our knowledge pretty nearly limited to that of the fact, that the only chance growing the crop with success is to allow a certain number years to elapse before repeating it on the same land. We ve experimented for some years on the subject with a view to certain, if possible, by what means the crop can be grown ar after year on the same land. In this we have not been suc- sful. Still it is thought that a short account of the course rsued, and of the results obtained, may be of service, by show- some of the difficulties involved in the inquiry, and by iiting or indicating the direction of future investigations.

Experiments on this farm have satisfactorily shown that some the crops which are generally grown in rotation, will yield a ge amount of produce year after year on the same land, on the plication of certain *constituents* as manure. Thus, a part of *same field, in which the* experiments on Clover now in ques- *were made, has grown* barley for ten years in succession, and

Experiments on the Growth of Red Clover by Different Manures.

Table I.—Showing the Description and Amount of Manures employed, and the Amount of Produce obtained per Acre.
First Season, 1849.

Plot, Nos.	MANURES per Acre.	PRODUCE per Acre. 3 Cuttings—June 25 and 28; August 6; October 19							
		Weights Fresh, as Cut.				Weights calculated as Hay.*			
	Series 1.—Unmanured, or with Mineral Manures alone.	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
1	Unmanured	14	1	3	6	3	15	0	14
2	Superphosphate of Lime (150 lbs. Bone-ash and 112½ lbs. Sulphuric Acid, sp. gr. 1·7)	15	5	2	16	3	19	3	4
3	300 lbs. Sulphate of Potash	17	19	2	18	4	17	2	8
4	300 lbs. Sulphate of Potash, and "Superphosphate of Lime"	16	19	3	5	4	9	2	20
5	Mixed Alkalies (300 lbs. Sulphate of Potash, 100 lbs. Sulphate of Soda, and 100 lbs. Sulphate of Magnesia)	18	1	0	0	4	11	0	21
6	"Mixed Alkalies," and "Superphosphate of Lime"	16	6	3	21	4	12	2	26
	Series 2.—With Ammonia Salts alone, or in addition to Mineral Manures.								
1	100 lbs. each, Sulphate and Muriate of Ammonia	14	17	0	18	3	18	1	26
2	100 lbs. each, Sulphate and Muriate of Ammonia, and "Superphosphate of Lime"	14	8	0	16	3	18	0	1
3	100 lbs. each, Sulphate and Muriate of Ammonia, and 300 lbs. Sulphate of Potash	13	10	1	17	3	11	0	11
4	100 lbs. each, Sulphate and Muriate of Ammonia, and 300 lbs. Sulphate of Potash and "Superphosphate of Lime"	17	12	2	22	4	9	3	16
5	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	17	10	0	22	4	14	2	20
6	100 lbs. each, Sulphate and Muriate of Ammonia, "Mixed Alkalies," and "Superphosphate of Lime"	17	10	0	2	4	12	0	2
	Series 3.—With Rape-Cake.								
1 2 3 4 5 6	1000 lbs. Rape-Cake	12	17	1	23	3	7	2	25

and on some plots large crops have always been obtained. In like manner, in an adjoining field, wheat has been successfully grown for seventeen years consecutively. Nor is there at present any thing in the results to lead to the supposition that these crops might not be so grown continuously for a century. The results of somewhat similar experiments with Clover are very different, as the records we are about to give will show.

In 1847 a heavy crop of swedish turnips was grown by farm-yard manure and superphosphate of lime, a large proportion of which was carted from the land. In 1848 barley and Red Clover were sown; and in the spring of 1849 four acres were set apart for experiment. These were divided into a number of plots, which were manured as shown in Table I.

As our object in the present short communication is to do little more than call attention to the great variety of conditions under which the Clover-plant has failed, we shall not enter, on this occasion, into any detailed examination of the action of the various manures, in regard either to the amount of produce obtained under the different circumstances of season and manuring, or to the chemical composition of the plant. It will be sufficient to point out, that, in every case, the crop of this first year of the experiment was a very large one; amounting, in three cuttings, to about 14 tons of fresh green produce, equal to about $3\frac{3}{4}$ tons of hay, without the addition of manure of any kind; and where sulphate of potash, sulphate of potash and superphosphate of lime, or sulphates of potash, soda, and magnesia, were employed, 17 to 18 tons of green produce (equal to from about $4\frac{1}{2}$ to nearly 5 tons of hay), per acre were obtained. When to the mineral manures were added those salts of ammonia which so greatly increase the produce of our Cereal crops, the produce of this Leguminous plant was upon the whole less than where the mineral manures were used alone. It will be seen too, that the rape-cake (Series 3) gave a smaller crop than either the mineral manures alone, or the mineral manures together with ammoniacal salts.

After the third cutting of Clover (1849) had been taken from the land, it was ploughed up and sown with wheat, about the middle of November, without any further manuring. The produce—corn, straw, &c.—is given in Table II.

It will be observed that the weight per bushel of corn, of this wheat-crop, scarcely in any case reached 58 lbs.; and in its case, as well as in that of an adjoining experimental field, the proportion of corn to straw was rather low. The wheat grown after the Clover on the unmanured plot gave, however, $29\frac{1}{2}$ bushels of corn, or 14 bushels more than was obtained in the adjoining field, where wheat was grown after wheat without manure. This result is quite *consistent* with that obtained in ordinary farm-practice. *It should be* observed, however, that in the unmanured Clover-crop

EXPERIMENTS on the GROWTH of RED CLOVER by DIFFERENT MANURES.

TABLE II.—Showingthe PRODUCE of WHEAT, without direct Manure, after the removal of 3 Cuttings of RED CLOVER, from plots of Land variously manured. HARVEST 1850.

Plot, Nos.	MANURES per Acre, applied in 1849 for the CLOVER.	PRODUCE OF WHEAT per Acre, &c.				
		Dressed Corn.	Weight per Bushel of Dressed Corn.	Total Corn.	Total Straw, &c.	Total Produce (Corn and Straw).
	SERIES 1.—Unmanured, or with Mineral Manures alone, in 1849.					
		Bush. Pks.	lbs. ozs.	lbs.	lbs.	lbs.
1	Unmanured	29 2	55 6	1792	3512	5304
2	Superphosphate of Lime (150 lbs. Bone-ash and 112½ lbs. Sulphuric Acid, sp. gr. 1·7)	32 2¾	56 14	2029	3811	5840
3	300 lbs. Sulphate of Potash	30 1½	55 4	1867	3906	5773
4	300 lbs. Sulphate of Potash, and "Superphosphate of Lime"	33 3¼	56 2	2097	4197	6294
5	Mixed Alkalies (300 lbs. Sulphate of Potash, 100 lbs. Sulphate of Soda, and 100 lbs. Sulphate of Magnesia)	31 1	56 6	1962	4088	6050
6	"Mixed Alkalies," and "Superphosphate of Lime"	33 1	55 15	2264	4176	6440
	SERIES 2.—With Ammonia Salts alone, or in addition to Mineral Manures, in 1849.					
1	100 lbs. each, Sulphate and Muriate of Ammonia	32 1¾	57 4	2058	3917	5975
2	100 lbs. each, Sulphate and Muriate of Ammonia, and "Superphosphate of Lime"	32 3	57 0	2062	3720	5782
3	100 lbs. each, Sulphate and Muriate of Ammonia, and 300 lbs. Sulphate of Potash	32 3	56 15	2031	3842	5873
4	100 lbs. each, Sulphate and Muriate of Ammonia, and 300 lbs. Sulphate of Potash and "Superphosphate of Lime"	36 0¾	57 11	2292	4296	6588
5	100 lbs. each, Sulphate and Muriate of Ammonia, and "Mixed Alkalies"	35 1	58 1	2253	4135	6388
6	100 lbs. each, Sulphate and Muriate of Ammonia, "Mixed Alkalies," and "Superphosphate of Lime"	33 2¼	56 11	2093	3967	6060
	SERIES 3.—With Rape-Cake, in 1849.					
1	1000 lbs. Rape-Cake	27 0¾	56 10	1781	3520	5301
2		30 1¾	57 13	1916	3692	5608
3		25 2¾	55 15	1695	3468	5163
4		29 2¼	56 10	1910	3822	5732
5		31 3	57 9	2002	3795	5797

rop of 1849, very much larger quantities both of mineral
nts and of nitrogen were taken off the land, than were
in the unmanured wheat-crop in the same year, in the
; field; and it is seen that, notwithstanding this, the
which the Clover had been taken, was in a condition to
ushels more wheat per acre than that upon which wheat
previously grown.

: salts of ammonia had been applied, in addition to the
manures, for the Clover of 1849, there was an average
2 bushels more wheat per acre in 1850, than where the
-salts had not been supplied.

mparing the amount of produce of wheat in these experi-
rith that obtained in the adjoining field on the plots
rge quantities of both mineral and nitrogenous manures
ployed, there is every reason to believe that it would
n considerably greater had the season been more favour-
or, as it was, the yield after the Clover, was fully equal
n the other field where very large amounts of manure
d. It would appear, therefore, that the crop had reached
of development which the characters of that particular
lmitted of.

spring of 1850, Red Clover was sown upon the young
ut after the removal of the corn-crop, it was considered
e was not a sufficient plant of Clover to stand. It was,
, ploughed up, re-manured, and re-sown with Clover, as
l below.

ume mineral manures as were applied for the Clover-crop
were re-sown on the same spaces—that is, both on the
ich before received mineral manure alone, and on those
ad received both mineral manure and ammoniacal-salts.
lication of ammoniacal salts was, however, not repeated;
rder to secure a greater variety of manuring, a portion
ots which had before been dressed with mineral manure
eries 1 of Tables I. and II.), and an equal portion of
merly manured with both mineral manure and ammo-
ılts (Series 2 of Tables I. and II.), were now manured
ompost of dung and lime (in addition to the newly-
mineral manures), at the rate of 15 tons of farmyard-
and 60 bushels of fresh lime, per acre. The dung and
e mixed, and then clamped on the respective plots, some
ore being spread and ploughed into the land. The
this experiment was to get a more rapid decomposition
ng, with possibly the formation of certain organic com-
somewhat of the nature of humus or its derivatives.
lar reasons the portion of the experimental land manured
-cake in 1849, was now divided, and manured with soot;
t and lime; or with soot, lime, the mixed alkalies, and
sphate of lime.

ammoniacal-salts having been
Series 4. With soot, soot and
mixed mineral manure; thes
with rape-cake in 1849.

With these explanations, the det
applied, and of the produce obtai
be at once understood. It may be
of the plots of Series 1, 2, and 3,
with clay-ashes) were sown on
same day the dung and lime wer
plots of Series 2; the mineral m
Series 2, being mixed with the du
sown at once as in the other cas
lime were turned over on the 10t
April 28. The manures of Seri
mixed into heaps on the respectiv
sown February 3. The whole of t
diately after spreading the dung
being brought to a proper tilth, Re
May 8, in rows 8 inches apart. T
the crop was cut on September 3.
and produce are given in Table III.

It was not to be expected that t
tember, from seed sown only on M
be in any way equal to that yielded
the case, in the spring of the preced
seen that the maximum

Second Season, 1851.

Plot Nos.	MANURES, per Acre, for the Clover of 1851.	PRODUCE, per Acre, Cut September 1 and 3, 1851.	
		Weight Fresh, as Cut.	Weight, calculated as Hay.
	Series 1.—Unmanured, or with Mineral Manures alone (the same as in 1849).		
		tons. cwts. qrs. lbs.	tons. cwts. qrs. lbs.
1	Unmanured	1 15 2 8	0 8 3 5
2	Superphosphate of Lime (150 lbs. Bone-ash and 112½ lbs. Sulphuric Acid, sp. gr. 1·7)	1 1 0 12	0 5 1 9
3	300 lbs. Sulphate of Potash	2 4 0 24	0 11 1 0
4	300 lbs. Sulphate of Potash, and "Superphosphate of Lime"	4 0 0 19	0 19 1 23
5	Mixed Alkalies (300 lbs. Sulphate of Potash, 100 lbs. Sulphate of Soda, and 100 lbs. Sulphate of Magnesia)	4 12 1 12	0 19 2 25
6	"Mixed Alkalies," and "Superphosphate of Lime"	4 17 3 26	1 2 2 19
	Series 2.—With Farmyard Manure and Lime, either alone, or with Mineral Manures in addition (Ammonia-salts, &c., on Half of each Plot in 1849).		
1	15 tons Farmyard Manure with 3720 lbs. Lime	2 9 0 11	0 11 2 25
2	15 tons Farmyard Manure with 3720 lbs. Lime, and "Superphosphate of Lime."	2 4 2 13	0 10 2 23
3	15 tons Farmyard Manure with 3720 lbs. Lime, and 300 lbs. Sulphate of Potash	2 18 2 12	0 13 3 12
4	15 tons Farmyard Manure with 3720 lbs. Lime, and 300 lbs. Sulphate of Potash, and "Superphosphate of Lime"	5 1 0 0	1 3 1 7
5	15 tons Farmyard Manure with 3720 lbs. Lime, and "Mixed Alkalies"	4 12 1 12	1 0 2 1
6	15 tons Farmyard Manure with 3720 lbs. Lime, and "Mixed Alkalies," and "Superphosphate of Lime"	5 5 1 4	1 3 2 0
7	15 tons Farmyard Manure with 3720 lbs. Lime, and "Mixed Alkalies," and "Superphosphate of Lime"	5 9 2 0	1 6 0 2
	Series 3.—Unmanured, or with Mineral Manures alone (Ammonia Salts alone, or with Mineral Manure, in 1849).		
1	Unmanured	1 18 2 25	0 9 1 4
2	"Superphosphate of Lime"	1 16 2 9	0 9 0 7
3	300 lbs. Sulphate of Potash	2 13 0 21	0 13 0 25
4	300 lbs Sulphate of Potash, and "Superphosphate of Lime"	4 8 3 14	1 0 0 0
5	"Mixed Alkalies"	4 10 2 21	1 0 0 27
6	"Mixed Alkalies," and "Superphosphate of Lime"	4 16 2 9	1 3 0 20
	Series 4.—With Soot, &c. (Rape Cake, in 1849).		
1 2	1240 lbs. Soot	2 10 3 2	0 12 2 12
3 4	1240 lbs. Soot and 1240 lbs. Lime	3 18 2 25	0 18 3 16
5 6	1240 lbs. Soot, and 1240 lbs. Lime, "Mixed Alkalies," and "Superphosphate of Lime"	4 18 3 1	1 2 3 27

Instead therefore of three Series of plots as formerly, the experimental land was now divided into four Series, as under:—

Series 1. With mineral manure alone (excepting on Plot I.), as in 1849.

Series 2. With mineral manure (excepting on Plot I.), and a mixture of farmyard-manure rotted with lime, in addition; half of each plot having, in 1849, the mineral manure alone, and the other half the mineral manure and ammoniacal-salts.

Series 3. With mineral manure alone (excepting on Plot I.), ammoniacal-salts having been also applied in 1849.

Series 4. With soot, soot and lime, or soot, lime, and the mixed mineral manure; these plots having been manured with rape-cake in 1849.

With these explanations, the detailed statement of the manures applied, and of the produce obtained, given in Table III., will be at once understood. It may be added, however, that on most of the plots of Series 1, 2, and 3, the mineral manures (mixed with clay-ashes) were sown on January 25, 1851. On the same day the dung and lime were mixed and clamped on the plots of Series 2; the mineral manures of Plots V. and VI., Series 2, being mixed with the dung and lime, instead of being sown at once as in the other cases. The heaps of dung and lime were turned over on the 10th of February, and spread on April 28. The manures of Series 4 (soot, lime, &c.) were mixed into heaps on the respective plots on January 27, and sown February 3. The whole of the land was ploughed immediately after spreading the dung and lime, on April 28; and, being brought to a proper tilth, Red Clover seed was *drilled*, on May 8, in rows 8 inches apart. The plants came up well, and the crop was cut on September 3. The details of the manuring and produce are given in Table III.

It was not to be expected that the produce obtained in September, from seed sown only on May 8 of the same year, would be in any way equal to that yielded from seed sown, as is usually the case, in the spring of the preceding year. Accordingly, it is seen that the maximum crop (Plot 7, Series 2) amounted to only 5 tons 9½ cwts. of green-clover, equal to about 1 ton 6 cwts. of hay.

On comparing the produce of Plots 1, 2, and 3, of Series 1, 2, and 3, with that of Plots 4, 5, and 6, of the same Series, it will be seen that the crop on the latter was about double that on the former; the Plots 4, 5, and 6, which thus give so much the higher amounts of produce, being those which received as mineral manure—sulphate of potash, and superphosphate of lime—sulphates of potash, soda, and magnesia—or sulphates of potash, soda, and magnesia, and superphosphate of lime together.

The

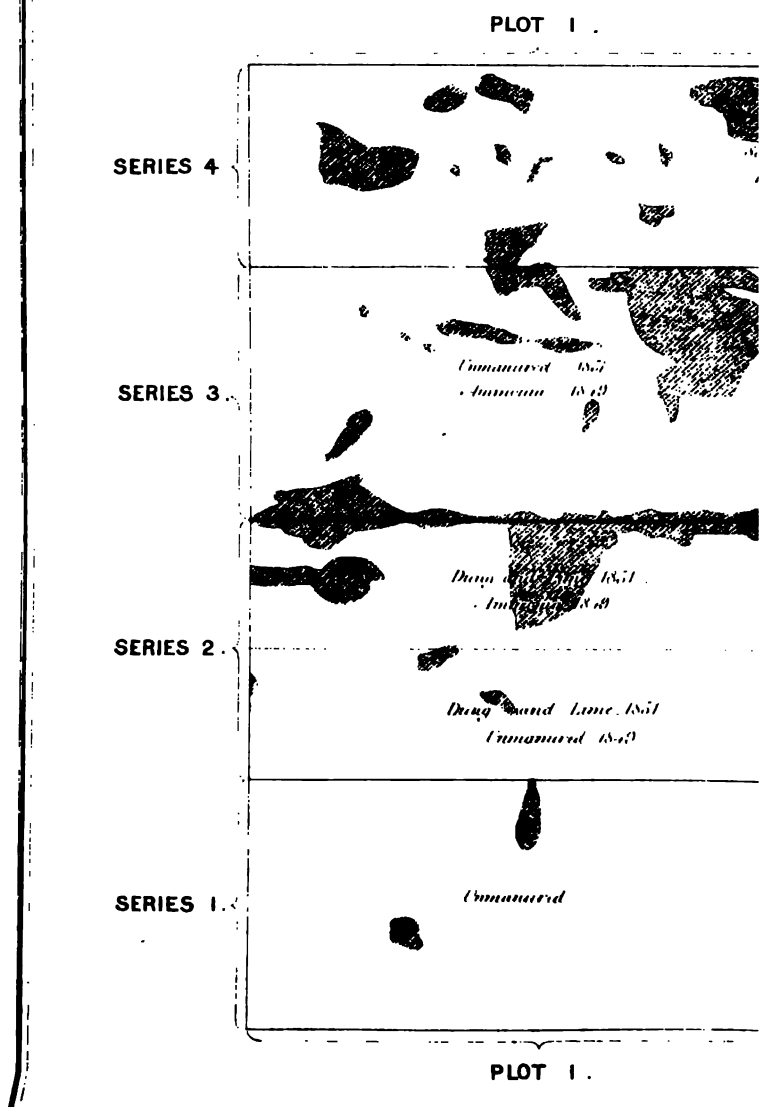
The dung and lime (Series 2), and soot and lime (Series 4), produced but very little effect. The greatest increase obtained by the addition to the mineral manures of the dung and lime compost (at the rate of 15 tons of dung and 60 bushels of lime per acre), beyond the produce from the corresponding mineral manures used alone, was only equal to 4 or 5 cwts. of hay.

In the autumn, after the crop was cut, the plant grew remarkably well, and was very regular throughout the plots. It was therefore left without further treatment during the winter of 1851-2.

Those who have paid attention to the spread of disease in Clover, on land which is said to be "clover-sick," will have observed that, however luxuriant the plant may be in the autumn and winter, it will show signs of failure in March or April, the spread and final limit of the disease being, however, subject to great variation. In the month of March, 1852, symptoms of failure became apparent on many of the experimental plots. It was quite plain however that the spread of the disease was much more extensive and rapid on some of them than on others. And, since such a great variety of manures had been employed, it was thought very desirable to determine the effect of the different conditions of growth so provided, in aggravating, or lessening, the progress of the failure. Accordingly, on April 15, when the disease had extended pretty nearly to its limits, and the surviving plants were showing vigorous growth, a plan of the plots, with the patches where the plant had died off, carefully laid down by measurement, was made, of which the annexed Diagram is a copy.

The black lines show the division of the plots at the time the plan was taken. The dotted line, along the centre of the plots marked Series 2, shows the division between the portion which was manured with ammonia-salts in 1849, and that which was not so manured. As already described, the plots of "Series 2," of 1851 and afterwards, to which farmyard-manure and lime were then applied, comprised a portion of land on each side of the line indicated on the plan by this dotted line; that is to say, a portion which had, and a portion which had not, been manured with ammonia-salts in 1849. The shaded portions show the patches where the Clover-plant had died off.

On the first glance at the Diagram, it is seen that the plots which had not been manured with either farmyard-manure, ammonia-salts, or rape-cake (Series 1), were by far the freest from disease. The next in order in this respect was that half of Series 2 indicated below the dotted line; that is to say, the portion of the dung and lime plots which had not been manured with ammonia-salts in 1849. The other half of the plots of Series 2, namely, the portions which had received ammonia-salts in 1849—the plots of Series 3, which had also received ammonia-salts


PLOT 1.
SERIES 4
SERIES 3.
SERIES 2.
SERIES 1.
Unmanured
Dung and Lime 1851
Unmanured
PLOT 1.

1849—and those of Series 4, which had been manured with pe-cake in that year, all show a very great failure of the plant. is, however, equally clear, that the Plots 4, 5, and 6 of these ries (with the exception of Plot 6, Series 4) were much less ected than Plots 1, 2, and 3 of the same Series; that is to say, hough the ammonia-salts and the rape-cake seemed to have ovided conditions in the soil very injurious to the healthy velopment of the Clover, the sulphate of potash, and super-osphate of lime (Plots 4), and the sulphates of potash, soda, d magnesia, both without and with superphosphate of lime lots 5 and 6), obviously greatly mitigated the injury, whilst they em almost to have prevented it, up to the date now in question, here they were used without either ammonia-salts or rape-ke.

In some cases, as will be readily seen from the number and the e of the patches, the produce was considerably reduced by the isease. But there was still, upon the whole, a good plant maining, and such variety of result in regard to the disease, cording to the manure employed, that it was thought quite orth while to continue the experiment. Acordingly, the crop as cut on June 24 (1852), fresh manures were applied on June 6, and a second crop was cut August 29. In Table IV. are iven the amounts of produce obtained at the first cutting, the escription and amount of the manure sapplied, and the amount f produce at the second cutting.

The produce of the first cutting of the Clover, in 1852, is given in the first two columns of the Table (IV.). It will be seen that it is in no case equal in amount to 2 tons of hay per acre. On comparing the amount of crop on the plots of one Series with that on those of another, it is seen that it is generally the highest where only the mineral manures were used, that is, in Series 1. It is the next best in Series 2, where, in addition to mineral manures, dung and lime had been used in 1851. It is less in Series 3, where, with the same mineral manures in 1851, as in Series 1 and 2, ammonia-salts, with or without mineral manures, had been employed in 1849; and it is the worst in Series 4, where rape-cake had been supplied in 1849, and soot, lime, &c., in 1851. The results within each Series, however, show a greater produce where sulphate of potash and superphosphate of lime, the "mixed alkalies," and the "mixed alkalies" and super-phosphate of lime together, were employed.

There was then, as before, some benefit arising from the use of mineral manures, especially those which contained *potash* and *phosphoric acid*. And as the object of the experiments was to ascertain whether by liberal manuring, and especially by a supply of the mineral constituents which the Clover crop removes so largely from the soil, it were possible to grow the crop year after *year on the same land*, an abundant top-dressing of mineral constituents

EXPERIMENTS on the GROWTH of RED CLOVER by DIFFERENT MANURES.

TABLE IV.—Showing the AMOUNT of PRODUCE obtained per Acre in the FIRST CROP, the DESCRIPTION and AMOUNT of MANURES Employed, and the AMOUNT of PRODUCE afterwards obtained in the SECOND CROP.

THIRD SEASON, 1852.

Plot, Nos.	Produce per Acre. 1st Cutting, June 24, 1852. Weight Fresh, as Cut.				Produce per Acre. 1st Cutting, June 24, 1852. Weight, calculated as Hay.				MANURES Per Acre, Sown June 26, 1852.	Produce per Acre. 2nd Cutting, August 29, 1852. Weight, Fresh, as Cut.				Produce per Acre. 2nd Cutting, August 29, 1852. Weight, calculated as Hay.				Total Produce per Acre, 1852. 1st and 2nd Cuttings. Weight Fresh, as Cut.				Total Produce per Acre, 1852. 1st and 2nd Cuttings. Weight, calculated as Hay.			
	ton.	cwt.	qr.	lb.	ton.	cwt.	qr.	lb.		ton.	cwt.	qr.	lb.	ton.	cwt.	qr.	lb.	ton.	cwt.	qr.	lb.	ton.	cwt.	qr.	lb.
SERIES 1.—Unmanured, or with Mineral Manures Alone, in 1852, 1851, and 1849.																								
1	4	14	2	8	1	3	2	12	Unmanured	2	17	0	27	0	16	3	25	7	11	3	7	2	0	2	9
2	5	3	3	7	1	4	3	18	Superphosphate of Lime (300 lbs. Bone-ash and 225 lbs. Sulphuric Acid, sp. gr. 1·7)	2	15	0	11	0	17	2	8	7	18	3	18	2	2	1	26
3	5	1	0	7	1	4	2	14	500 lbs. Sulphate of Potash	3	3	2	4	0	19	0	10	8	4	2	11	2	3	2	24
4	7	13	0	3	1	16	0	24	500 lbs. Sulphate of Potash, and "Superphosphate of Lime"	3	13	2	16	1	2	2	22	8	6	2	19	2	16	3	18
5	7	3	0	6	1	12	1	14	(Mixed Alkalies (500 lbs. Sulphate of Potash, 225 lbs. Sulphate of Soda, and 100 lbs. Sulphate of Magnesia)	3	8	1	27	0	14	3	14	10	11	2	5	2	7	1	0
6	6	13	2	20	1	12	1	17	"Mixed Alkalies," and "Superphosphate of Lime"	3	0	0	6	0	19	1	11	9	13	2	26	2	11	3	0
SERIES 2.—Unmanured, or with Mineral Manures Alone, in 1852; with Farmyard Manure and Lime, either Alone or with Mineral Manures in Addition, in 1851; and with Ammonia-Salts Alone, or with Mineral Manures, on Half of each Plot, in 1849.																								
1	3	16	0	17	0	18	2	5	Unmanured	2	0	1	13	0	12	3	17	5	16	2	2	1	11	1	22
2	5	3	1	3	0	12	0	0	Superphosphate of Lime (300 lbs. Bone-ash and 225 lbs. Sulphuric Acid, sp. gr. 1·7)	2	1	3	2	0	14	1	22	7	5	0	5	1	6	1	22
3	5	2	3	14	1	4	2	5	500 lbs. Sulphate of Potash	2	9	2	27	0	15	3	25	7	12	2	13	2	0	2	2
4	8	8	2	22	1	19	1	2	500 lbs. Sulphate of Potash, and "Superphosphate of Lime"	3	5	0	23	1	2	1	16	11	13	3	17	3	1	2	18
5	7	5	2	11	1	12	2	27	(Mixed Alkalies (500 lbs. Sulphate of Potash, 225 lbs. Sulphate of Soda, and 100 lbs. Sulphate of Magnesia)	2	14	3	16	0	16	3	12	10	0	1	27	2	9	2	11
6	6	19	2	15	1	12	3	6	"Mixed Alkalies," and "Superphosphate of Lime"	3	0	3	27	0	18	3	22	10	0	2	14	2	11	3	0
7	6	12	2	1	1	11	3	2	"Mixed Alkalies," and "Superphosphate of Lime"	1	18	1	27	0	13	1	15	8	1!	0	.0	2	5	0	17
SERIES 3.—Unmanured, or with Mineral Manures Alone, in 1852, and 1851; Ammonia-Salts Alone, or with Mineral Manure, in 1849.																								
1	2	13	2	25	0	13	3	22	Unmanured	1	4	1	20	0	7	2	27	3	18	0	17	1	1	2	21
2	3	0	3	15	0	14	3	3	"Superphosphate of Lime"	1	10	3	27	0	11	1	6	4	11	3	14	1	6	0	9
3	3	19	3	25	0	19	2	22	500 lbs. Sulphate of Potash	2	5	0	6	0	13	2	18	6	5	0	3	1	13	1	12
4	6	3	2	22	1	7	2	23	500 lbs. Sulphate of Potash, and "Superphosphate of Lime"	2	10	0	23	0	16	3	9	8	13	3	17	2	4	2	3
5	7	4	1	16	1	12	1	20	"Mixed Alkalies"	2	19	2	9	0	19	3	13	10	3	3	25	2	12	1	5
6	4	11	1	12	1	2	0	9	"Mixed Alkalies," and "Superphosphate of Lime"	1	19	1	20	0	12	2	24	6	10	3	4	1	14	3	5
SERIES 4.—With Mineral Manures Alone in 1852; with Soot, Soot and Lime, or Soot, Lime, and Mineral Manures, in 1851; and Rape-Cake in 1849.																								
1	3	15	3	26	0	19	0	2	300 lbs. Sulphate of Potash	1	18	0	20	0	12	2	23	5	14	0	18	1	11	2	25
2	2	9	1	26	0	12	2	16	900 lbs. Sulphate of Soda	1	13	0	10	0	12	0	21	4	2	2	8	1	4	3	9
3	2	5	2	6	0	17	0	15	700 lbs. Sulphate of Magnesia	1	13	0	0	0	11	2	4	4	18	2	6	1	8	2	19
4	5	16	1	2	1	6	1	17	500 lbs. Sulphate of Potash, and "Superphosphate of Lime"	2	14	1	20	0	18	0	22	8	10	2	22	2	6	2	11
5	7	1	2	14	1	12	3	17	900 lbs. Sulphate of Soda, and "Superphosphate of Lime"	2	2	2	6	0	15	0	12	9	4	0	20	2	8	0	11
6	5	1	2	4	0	14	3	11	700 lbs. Sulphate of Magnesia, and "Superphosphate of Lime"	1	11	3	20	0	11	0	5	4	13	2	16	1	5	3	16

stituents was applied on June 28 (1852), after the removal of the first cutting. The second division of the Table (IV.) shows the description, and amount, of the manures employed; and the third division the amount of crop obtained on August 29.

The produce, after the heavy dressing of mineral manure upon the removal of the first cutting, is seen to be, in every case, small. In only two instances is it equal to more than a ton of hay per acre, namely, on Plot 4, Series 1 and 2; that is, where sulphate of potash and superphosphate of lime were applied. In all the Series, however, the effect of the potash, and of the potash and phosphate together, is more or less marked. In fact, notwithstanding that this was the third season of Clover in four years, the produce with these manures, taking the two cuttings of 1852 together, was, in several cases, equal to from 2½ to 3 tons of hay per acre.

A good deal of the plant stood tolerably well during the winter of 1852-3, but almost all died off in the spring. The land was therefore ploughed up, and fresh Red Clover-seed *drilled* in April, in rows 20 inches apart, in order to admit of the use of the horse-hoe. The plant came up very weak; there was no crop worth cutting in the autumn; and nearly the whole died off during the winter of 1853-4.

In the spring of 1854, the land was again ploughed up, and allowed to remain fallow until September. The whole piece consisted of 15 "lands," each 13 feet 3 inches wide, divided into 6 lengths, forming the 6 "Plots" numbered from 1 to 6 respectively, in the Tables. It was now divided into three widths only, of 5 lands each, represented in subsequent Tables as Series 1, 2, and 3.* One of these (Series 1), the whole length of the 6 plots of course, was left unmanured; the second (Series 2) was manured with 20 tons of farmyard manure down the whole length of the 6 plots; and the third (Series 3), also throughout the 6 plots, was manured with 20 tons of farmyard manure, and 5000 lbs. of freshly burnt lime, per acre. These were ploughed in on September 25, 1854, and Clover-seed was drilled on October 10. Plants just came up, but all died off during the winter of 1854-5.

Clover-seed was again drilled on April 14, 1855, at the rate of 20 lbs. per acre, without further manure. The following

* The Plots designated in Tables III. and IV. as Series 1, 2, and 3, consisted of four lands each; and those as Series 4, of three lands, each running the length of the six Plots which had either no mineral manure, or one of the five different descriptions enumerated in the Tables. Under the new arrangement, Series 1 (now to be unmanured) includes the four lands of the former Series 1, which from the beginning were manured with mineral manures only, and one land of the former Series 2, which had the dung and lime applied in 1851; Series 2 (now to be manured with farmyard manure alone) includes the remaining three lands of the former Series 2, and two lands of the former Series 3, which, besides the several dressings of mineral manures, was manured in 1849 with ammonia salts; and Series 3 (now to receive farmyard manure and freshly burnt lime) includes the two remaining lands of the former Series 3, and the three lands of the former Series 4, which latter (besides the mineral manures as specified) were manured with rape-cake in 1849, and with soot, lime, &c. in 1851.

Table (V.) shows the manures applied in 1854, and the produce of Clover obtained in September, 1855, without manure since 1854, but after a second and heavy sowing of seed.

EXPERIMENTS on the GROWTH of RED CLOVER by DIFFERENT MANURES.

TABLE V.—Showing the MANURES applied in 1854, and the PRODUCE of CLOVER, obtained in September, 1855, from Seed sown in April of that year, after the failure of Seed sown in April, 1853, and in October, 1854.

SIXTH SEASON, 1855.

Plot, Nos.	MANURES per Acre. Put on September 25, 1854.	PRODUCE OF CLOVER per Acre, September, 1855.							
		Weight Fresh, as Cut.				Weight calculated as Hay.			
	SERIES 1.								
		tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
1	Unmanured	1	7	3	6	0	4	2	14
2		1	14	3	2	0	5	3	4
3		1	13	1	26	0	5	0	18
4		3	11	2	26	0	11	3	21
5		2	16	1	18	0	9	1	15
6		3	18	0	6	0	12	3	26
	SERIES 2.								
1	20 tons Farmyard Manure	4	12	2	2	0	19	3	22
2		3	14	0	4	0	15	3	24
3		3	15	1	2	0	16	0	26
4		5	6	0	8	1	2	3	13
5		5	4	3	16	1	2	2	13
6		5	12	3	2	1	4	1	8
	SERIES 3.								
1	20 tons Farmyard Manure, and 5000 lbs. fresh-burnt Lime	4	1	3	6	1	0	0	16
2		2	17	2	10	0	14	0	20
3		3	6	2	4	0	16	1	15
4		3	12	3	12	0	17	3	21
5		4	3	2	2	1	0	2	7
6		3	5	0	22	0	16	0	6

The figures in the Table show that the produce in this sixth season of the attempt to grow Clover continuously on the same land, and after two years of entire failure, was in every case small. Comparing Series with Series, the crop is the best where the farmyard manure alone was employed; the next best, where the Farmyard manure and Lime were used; and it was the worst where no manure was now employed, and where, for the most part, mineral manures alone had previously been employed. Still, comparing the results within each Series, there is again *evidence* of some increase on those plots which had formerly received manures containing potash, and phosphoric acid.

The plant of 1855 died off in the succeeding winter. The

ploughed up and allowed to remain fallow during 1856
7.

spring of 1858, it was decided to take a crop of Barley,
manure, before making any further attempt to grow
It was, however, not thought worth while to determine
nce of Barley on each of the many differently manured
lots separately. Accordingly, only the main divisions,
ed by the Series 1, 2, and 3, of 1854 and 1855, were
The produce of Barley, per acre, over each of these
tions of land, is shown in Table VI.

ENTS on the GROWTH of RED CLOVER by DIFFERENT MANURES.

.—Showing the MANURES applied for CLOVER in 1854, and the
E of BARLEY in 1858, after the removal of a small Crop of Clover in
ie Sixth Season), and a Fallow in 1856 and 1857.

MANURES per Acre, for Clover, in 1854.	PRODUCE OF BARLEY per Acre, &c., in 1858.				
	Dressed Corn.	Weight per Bushel of Dressed Corn.	Total Corn.	Total Straw, &c.	Total Produce. (Corn and Straw).
SERIES 1.					
	bush. pks.	lbs.	lbs.	lbs.	lbs.
nanured	58 0	52·0	3181	3417	6598
SERIES 2.					
tons Farmyard Manure ..	65 2	52·0	3562	4016	7578
SERIES 3.					
ons Farmyard Manure, and 00 lbs. fresh-burnt Lime	64 0	52·5	3486	3738	7224

bvious, that although the land was incapable of yielding a
Red Clover, it embraced all the conditions requisite for
uction of a very luxuriant crop of Barley. The lowest
that on the plots of Series 1, of this "clover-sick" land,
uarters of Barley per acre, of 52 lbs. weight per bushel.

The highest produce, that on the plots of Series 2, where the Farmyard manure alone had been applied in 1854, was about 8½ quarters; and that where the Farmyard manure and Lime were used together (in 1854), was just 8 quarters of Barley, weighing 52½ lbs. per bushel.

After growing this luxuriant crop of Barley, one more attempt to grow Clover was made, but without any further manuring. In the spring of 1859, Clover-seed was sown, without a corn crop; but by a mistake of the seedsman, Cow-grass, instead of Red Clover, was sent, and the error was only discovered when it was too late for correction. The crop was cut in September. The amount of produce on each plot is recorded in Table VII. which now follows:—

EXPERIMENTS on the GROWTH of CLOVER by DIFFERENT MANURES.

TABLE VII.—Showing the MANURES applied for CLOVER in 1854, and the PRODUCE of CLOVER in 1859, after the removal of a small Crop of Clover in 1855 (the Sixth Season), Fallow in 1856 and 1857, and after removing a Crop of Barley in 1858.

Plot, Nos.	MANURES Per Acre, for Clover, in 1854.	PRODUCE OF CLOVER per Acre, September, 1859.							
		Weight Fresh, as Cut.				Weight calculated as Hay.			
		tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
SERIES 1.									
1	Unmanured	2	9	1	22	0	17	1	18
2		3	5	2	8	1	0	3	11
3		3	1	3	8	1	1	0	11
4		3	10	3	8	1	2	3	8
5		3	12	2	22	1	3	2	3
6		4	4	1	8	1	7	1	14
SERIES 2.									
1	20 tons Farmyard Manure .. - ..	3	13	3	8	1	3	1	7
2		4	2	1	22	1	4	1	19
3		4	11	1	22	1	7	0	10
4		4	5	1	22	1	6	1	1
5		4	11	3	8	1	8	3	1
6		4	6	2	8	1	7	2	24
SERIES 3.									
1	20 tons Farmyard Manure, and 5000 lbs. freshly-burnt Lime	4	13	2	22	1	7	3	16
2		4	10	1	8	1	5	3	2
3		4	15	0	22	1	7	1	10
4		5	5	1	8	1	8	2	13
5		5	0	3	8	1	9	0	12
6		5	4	3	4	1	10	3	6

As in the case of the last crop of Clover, that of 1855, the year after the heavy dressing of Farmyard manure on one-third, and of Farmyard manure and Lime on another third of the experimental land, the so-manured portions, again, in 1859, yield a somewhat larger crop than the corresponding plots of Series 1, which had no such application. The plots of each Series, however, yield somewhat more produce in 1859, than they did in 1855. The crops are, however, in all cases, insignificant, being generally equal to not much more than 1 ton of hay per acre; but there is still slight indication of improvement where the mineral manures containing potash, or potash and phosphoric acid, had been liberally employed in the earlier years of the experiment.

The plant continued to look tolerably well throughout a good part of the winter (1859-60), but as the spring advanced it died off rapidly, and, at the time we write, the end of June, the small proportion of the original plants that still survive have a very stunted and unhealthy appearance.

From the numerous results which have been recorded, in the foregoing pages, of experiments in which Clover has been submitted to a very great variety of manurial, and other conditions of growth, it is evident that no direct supply of manure, in the ordinary form of farmyard dung, or of the current artificial manures, is capable of restoring the soil from which a heavy crop of Clover has been taken, to a condition of immediate productiveness for the same crop. In the experiments in question, not even the most complex conditions, and the repeated supply of those constituents which are found most to increase the Clover-crop when it is grown in the usual manner, after an interval of several years, have restored the Clover-yielding capabilities which the soil possessed at the commencement of the experiment, in 1849.

Before entering upon any consideration of the probable causes of the failure of the Clover in the experiments which have been already described, it will be well to give the results of some experiments conducted on a small scale in the kitchen-garden at Rothamsted. The soil was in ordinary garden cultivation, and has probably been so for two or three centuries. Early in 1854, $\frac{1}{500}$ of an acre (about $9\frac{3}{4}$ square yards) was measured off and sown with Red Clover, on March 29. From that time to the end of 1859, fourteen cuttings have been taken, without any re-sowing of seed. In 1856, this little plot was divided into three equal portions. Of these, No. 1 has been kept continuously without manure; No. 2 was manured with gypsum; and No. 3 with sulphates of potash, soda, and magnesia, and superphosphate of lime. Table VIII. shows the amount of produce obtained, both green, as cut, and calculated as hay, per acre; but as the space

allotted to each experiment was so extremely small, the results must by no means be taken as absolutely correct. They can, indeed, be only looked upon as rough approximations; but, as such, they may be trusted as indicating the large amount of produce of Clover that has been taken from this garden soil, and as affording some idea of the relative amount of produce under the three different conditions of manuring.

The estimated total amount of green Clover obtained in six years from this garden soil, without further manure, is about 126 tons per acre—equal to about 26½ tons of hay, or to an average of nearly 4½ tons of Clover-hay, per acre, per annum. The produce was considerably increased by the application of gypsum, and still more so by that of the sulphates of potash, soda, and magnesia, and superphosphate of lime. In four years, the increase by the use of gypsum amounted to about 15½ tons of green Clover, or about 3½ tons of hay—nearly 1 ton of hay per acre per annum. The increase in the four years, by the use of the alkalies and phosphate, is estimated to amount to 28¾ tons of green produce, or rather more than 6½ tons of hay—equal to nearly 1¾ tons increase of hay per acre per annum.

It is worthy of remark, that it was in some of the very same seasons in which these heavy crops of Clover were obtained from the garden-soil, even though grown year after year, and without fresh seed, that we entirely failed to get anything like a moderate crop of Clover in the experimental field, only a few hundred yards distant. The failure in the latter case would, therefore, appear to be connected with the conditions of *soil* in relation to the plant, rather than to those of the *atmosphere*.

We now come to another and not very satisfactory part of our task; namely, that of endeavouring to seek, among the various causes of Clover-failure which have been suggested, for some explanation of the signal failure of the crop in our experimental field.

The comparison of the results in the garden with those in the field, seems to lead to the exclusion of some of the reasons enumerated in the early part of our Paper, as having been brought forward to account for the Clover failure. It may be well, however, to make a few passing remarks on some of them.

With regard to the *attacks of Insects*:—Those who have examined the plants on a field of Clover failing in the ordinary way, will probably sometimes have found a small insect in those plants which are beginning to show signs of dying off. It is generally found near the junction of the root and crown. Now, as experience teaches us that the plant seldom suffers serious injury if a sufficient number of years has elapsed since Clover was grown before,

TABLE VIII.—Showing the *estimated* PRODUCE per ACRE, of CLOVER grown 6 Years consecutively on the same Plots of Garden Soil, from One Sowing of Seed only.

	ESTIMATED PRODUCE PER ACRE.																			
	WEIGHED GREEN.												CALCULATED AS HAY.							
	Unmanured.				With Gypsum, applied May 22, 1856.				With Sulphates of Potash, Soda, and Magnesia, applied May 22, 1856.				Unmanured.				With Gypsum, applied May 22, 1856.				With Sulphates of Potash, Soda, and Magnesia, applied May 22, 1856.			
	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
1854—2 Cuttings	10	18	3	0	..		..		...		..		2	7	2	24	..		..		..		..	
1855—3 Cuttings	39	10	0	20	..		..		..		..		8	1	2	24	..		..		..		..	
1856—2 Cuttings	23	5	1	17	25	8	3	20	29	5	3	21	4	6	2	10	4	19	1	25	5	12	1	6
1857—3 Cuttings	27	10	3	3	30	16	3	18	33	2	0	12	6	2	0	14	6	14	1	10	7	6	0	25
1858—2 Cuttings	14	1	1	0	19	18	1	21	24	5	1	27	3	1	1	19	4	5	3	15	5	5	1	8
1859—2 Cuttings	10	17	2	15	14	19	2	18	17	18	1	1	2	7	2	0	3	7	0	1	4	6	0	7
Total Produce, 6 years ..	126	3	3	27	..		..		..		..		26	7	0	7	..		..		..		..	
Average Annual Produce, 6 years	21	0	2	18	..		..		..		..		4	7	3	10	..		..		..		..	
Total Produce, last 4 years	75	15	0	7	91	3	3	21	104	11	3	5	15	17	2	15	19	6	2	23	22	9	3	18
Average Annual Produce, last 4 years	18	18	3	2	22	15	3	26	26	2	3	22	3	19	1	18	4	16	2	20	5	12	1	25
Total Increase by Manure, last 4 years	..		..		15	8	3	14	28	16	2	26	..		..		3	9	0	8	6	12	1	3

before, it would appear that the prevalence of the insect, and its consequent injury to the plant, is the result, rather than the original cause, of the diseased condition. In fact, it is probable that the success of the attack of the insect upon the plant, may be mainly due to the weak or unhealthy condition of growth of the latter; and that, had the plant been perfectly vigorous, the insect would not be so freely developed, or its injury would at least be more successfully resisted.

Excrementitious Matters.—There is evidence of various kinds to show that plants give out certain substances by their roots to the soil. It is not probable, however, that any mineral constituents which may be so rejected during the growth of one Clover-crop, are prejudicial to the growth of a similar crop on the same land for a number of years to come. If the failure of the Clover-plant, when repeated too soon upon the same land, be due at all to the excrementitious matters left by the former crop, it is much more probable that the injury is in some way connected with the organic matters which have been rejected. Unfortunately, we are not yet able by the aid of chemistry to distinguish those organic compounds of the soil which are convertible into the substance of the growing plant, and those which are not so. Nor do we know how far the excreted organic matters may be necessary complimentary products in the formation of some of the essential constituents of the plant. Experience teaches us that when a crop of Clover is eaten by sheep folded upon the land, animals dislike the growth which immediately succeeds. It might be inferred, therefore, that, in such a case, the plant had taken up from the soil, certain matters which it had not finally elaborated. Whether these organic substances would, in process of time, be converted into living plant-matter, or whether they would wholly, or in part, be rejected as excrementitious organic compounds, to undergo in the soil certain chemical changes before being adapted for plant-food, we are not able to determine.

In connexion with this question, of whether or not the failure of the Clover-crop be due to the injurious influence of excrementitious organic matters, left by the last crop of the same kind, attention may be called to the fact, that in the case of the failure in our field experiments, two years of fallow, and one year of barley, intervened between the poor crop of Clover in 1855, and the almost equally poor one in 1859. *A priori*, we should certainly be disposed to think, that any deleterious matters left in the soil by the Clover-crop of 1855 would, under the circumstances in question, have undergone pretty complete decomposition during the three succeeding years. At the same time, it should be remembered that, in 1852, the plant of Clover suffered very much

more where Rape-cake, or Salts of Ammonia had been applied in 1849, than where mineral manures only had been employed.

Exhaustion of the Soil.—Some of the plots in the experimental Clover-field have doubtless been subjected to great exhaustion of certain constituents, by the removal of the whole of the produce, without adequate restoration by manure. On others, however, there has been considerable accumulation of constituents. Calculation shows, indeed, that, on many of the plots, there have been much larger quantities of every "mineral" constituent supplied in the manures, than have been removed in the total produce, during the entire period of the experiments. Of certain organic constituents, however, including nitrogen, more has been taken off in the crops than has been supplied in the manures. But if, in the cases in question, the produce grown without manure, be deducted from that grown with it, it then appears, that the manures have provided very much more, not only of the mineral constituents, but of nitrogen also, than was contained in the increase due to the manures. It cannot be supposed, therefore, that, in the instances here referred to, any of the ultimate elements of the crop could be wanting.

It should be remembered, too, that in some of the experiments mineral manures alone were employed, in others mineral manures and ammonia salts, and in others large quantities of farmyard dung, mineral manures, and ammonia salts, and so on; so that the proportions, and conditions of combination, in which the different constituents were supplied, were very variable.

How then are we to account for the fact, that whilst, under the conditions described, the Clover-plant would not grow healthily in the experimental field, we have been able to cut fourteen crops from seed sown six years ago in a garden only a few hundred yards distant? Are we to suppose, simply, that the ultimate constituents required by the Clover, were more abundantly available to the plant in the garden soil? or is it that they there existed in different states of combination? It will not be out of place to make a few observations bearing upon the latter supposition.

According to Mulder, who has investigated the organic compounds of the soil, the vegetable matters, rich in carbon, decomposing in the soil, go through a gradationary series of changes before being entirely converted into carbonic acid. He supposes the intermediate compounds to constitute a series of acids, which combine with ammonia, and with fixed bases, in the soil, forming so many organic-acid salts. Now, if we were to suppose that some plants (Clover for example) required for healthy growth a certain proportion of their food to be presented to them in the form of such carbon-compounds, more complex than carbonic acid, and perhaps combined with ammonia, we should then the

more easily comprehend why it should be necessary for a certain period of time to intervene before again cultivating certain crops on the same land; for, we could easily understand that this might be requisite for the gradual formation and accumulation of a sufficient amount of the compounds in question.

Whatever may be the precise chemical character of the carbon compounds of the soil, more complex than carbonic acid, there are numerous facts in horticulture, and even in agriculture, leading to the supposition that some plants take up a part at least of their carbon from some other form of combination than carbonic acid.

In one of our experimental fields we have grown very large crops of wheat for 17 consecutive years, without the supply, by manure, of a single ounce of carbon. The crops have been considerably greater on some plots where no carbon has been supplied in the manure, than on others to which it had been very largely supplied. There are, indeed, good reasons for supposing that carbonic acid is, at any rate, the chief, if not the exclusive source, of the carbon of many of the plants yielding food largely to man and other animals—which, by their respiration, return so much carbonic acid to the atmosphere. Were it not so, as forests make way for the growth of food, the proportion of carbonic acid in the atmosphere would gradually increase. The cultivation of the cereal crops, which enter so largely into the food of man and other animals, seems admirably adapted for preserving the equilibrium in the composition of the atmosphere; for an acre of wheat will decompose as much, or more, carbonic acid, liberating a corresponding amount of oxygen, as an acre of the forest which it may have supplanted.

Provided the soil yield a sufficient supply of the necessary mineral constituents, the amount of carbonic acid decomposed by a cereal crop over a given area, will very much depend upon the amount of nitrogen, in an available condition of combination, and distribution, within the soil. But the direct supply of nitrogen to the soil in the form of ammonia, which so much increases the vigour of growth of Graminaceous crops generally, and consequently the amount of carbon which the plants will assimilate from carbonic acid, so far from effecting the same result in the case of Leguminous crops, is generally injurious to them.

In the early years of our experiments, both upon Clover and upon Beans, the application of the fixed alkalies as manure, and especially of potash, caused a considerably increased assimilation of both carbon and nitrogen over a given area; whilst the direct use of ammonia-salts, which are so efficacious in the case of our Graminaceous crops, had either little or no such effect, or was more frequently injurious, in the case of these Leguminous crops. Where the supply of mineral constituents is sufficiently kept up, the supply of ammonia is as efficient as ever in enabling the wheat

growing in the experimental field to assimilate an increased amount of carbon from carbonic acid. The alkalies, potash, &c., have ceased to be as useful as manures for the Leguminous crops, as they were at the commencement of the experimental period; yet, so far as the atmosphere is a source of constituents to these plants, its supplies must be the same now as formerly. The decline in the beneficial influence of the potash, &c., would appear, therefore, to be connected with some defective condition within the soil.

If we were to assume that the Leguminous plants required a certain portion of their organic food to be supplied to them in the form of certain organic compounds in the soil, it is evident that the beneficial action of the potash, &c., would cease when these organic compounds were no longer available. On this assumption, too, it would seem intelligible, on the one hand, that an ordinary soil should require a considerable period of time after the growth of a Leguminous crop, to become again fertile for the same crop, and—on the other, that a garden soil, liberally manured with organic matter, perhaps for centuries, should support a considerable number of such crops in succession.

It is further worthy of remark, in connexion with the beneficial action of the alkalies as manures for Leguminous crops, and with the supposition that these crops may require a portion of their organic food in the form of certain carbon compounds which are more complex than carbonic acid, that it is chiefly by the aid of the alkalies that the organic compounds of the soil are rendered soluble. On recently cleared lands in America, where there is such a great accumulation of vegetable remains, the employment of ashes, and of gypsum, as top-dressings for Clover, has been attended with remarkable success. Vegetable ashes have been found to be beneficial to the crop in this country also, which, independently of the mere *supply* of potash, &c., may be partly due to the action above referred to. Gypsum, however, is by no means to be depended upon as a manure for Clover in this country. The action of gypsum has been very variously explained upon high authority. The following distinct explanations are on record, namely:—that it serves as a supply of sulphuric acid—that it serves as a supply of lime—that it serves as a supply of sulphur—and that it serves for the fixation of ammonia. It is perhaps not less likely that its beneficial action may be connected with changes in the organic matters of the soil. M. Risler has indeed shown, that an aqueous solution of gypsum will take up more organic matter from soil, than will water.

We are far from asserting that there is evidence enough to show that the failure of Clover, when grown too frequently on the same land, is altogether due to the want of a sufficient supply of certain organic compounds in the soil. At the same time, we think that the facts of horticultural and agricultural practice, as

well as the evidence of direct experiment, must lead to the conclusion, that the view—that the organic compounds of the soil are only valuable to plants as a source of carbonic acid—requires modification. It is, indeed, probable, that some plants derive a considerable amount of their substance from carbon compounds other than carbonic acid, and that others depend for their carbon mainly, if not exclusively, upon carbonic acid.

Those of our crops which, in the course of cultivation, are subjected to pretty natural conditions of growth, and which accumulate the greater portion of their substance during the period at which the sun's rays are known to be most powerful in influencing the decomposition of carbonic acid by plants, appear to depend chiefly on that source for their carbon. Those, on the other hand, which are grown under somewhat abnormal conditions, and which store up a large amount of succulent products of a comparatively low degree of elaboration, are probably partly dependent on other carbon compounds, yielded by the soil. The Leguminous crops, again, though generally coming more within the former than the latter category, still seem to be dependent, for luxuriant growth, more or less upon a supply, within the soil, of complex organic compounds.

But whatever may be the precise result to which investigation may lead, in regard to the questions here involved, it may, at any rate, be pretty safely affirmed, that we shall not arrive at the true explanation of the phenomena upon which depend some of the most striking advantages of a rotation of crops, until we are better able than at present, to define the relations of the different crops to the different sources of *carbon*, and of *nitrogen*.

The practical conclusions from the inquiry may be very briefly stated:—

When land is not what is called "clover-sick," the crop of Clover may frequently be increased by top-dressings of manure containing potash, and superphosphate of lime; but the high price of salts of potash, and the uncertainty of the action of manures upon the crop, render the application of artificial manures for Clover a practice of doubtful economy.

When land is what is called "clover-sick," none of the ordinary manures, whether "artificial," or natural, can be relied upon to secure a crop.

So far as our present knowledge goes, the only means of insuring a good crop of Red Clover is to allow some years to elapse before repeating the crop upon the same land.

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ON THE SOURCES

OF

THE NITROGEN OF VEGETATION;

WITH SPECIAL REFERENCE TO THE QUESTION

WHETHER PLANTS ASSIMILATE FREE OR UNCOMBINED NITROGEN.

BY

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(*ABSTRACT.*)

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ON

THE SOURCES

OF THE

NITROGEN OF VEGETATION;

ETC.

After referring to the earlier history of the subject, and especially to the conclusion of De Saussure, that plants derive their nitrogen from the nitrogenous compounds of the soil and the small amount of ammonia which he found to exist in the atmosphere, the Authors preface the discussion of their own experiments on the sources of the nitrogen of plants, by a consideration of the most prominent facts established by their own investigations concerning the amount of nitrogen yielded by different crops over a given area of land, and of the relation of these to certain measured, or known sources of it.

On growing the same crop year after year on the same land, without any supply of nitrogen by manure, it was found that wheat, over a period of 14 years, had given rather more than 30 lbs.—barley, over a period of 6 years, somewhat less—meadow-hay, over a period of 3 years, nearly 40 lbs.—and beans, over 11 years, rather more than 50 lbs. of nitrogen, per acre, per annum. Clover, another Leguminous crop, grown in 3 out of 4 consecutive years, had given an average of 120 lbs. Turnips, over 8 consecutive years, had yielded about 45 lbs.

The Graminaceous crops had not, during the periods referred to, shown signs of diminution of produce. The yield of the Leguminous crops had fallen considerably. Turnips, again, appeared greatly to have exhausted the immediately available nitrogen in the soil. The amount of nitrogen harvested in the Leguminous and Root-crops was considerably increased by the use of "mineral manures," whilst that in the Graminaceous crops was so in a very limited degree.

Direct experiments further showed that pretty nearly the same

amount of nitrogen was taken from a given area of land in *wheat* in 8 years, whether 8 crops were grown consecutively, 4 in alternation with fallow, or 4 in alternation with beans.

Taking the results of 6 separate courses of rotation, Boussingault obtained an average of between one-third and one-half more nitrogen in the produce than had been supplied in manure. His largest yields of nitrogen were in the Leguminous crops; and the cereal crops were larger when they next succeeded the removal of the highly nitrogenous Leguminous crops. In their own experiments upon an actual course of rotation, without manure, the Authors had obtained, over 8 years, an average annual yield of 57·7 lbs. of nitrogen per acre; about twice as much as was obtained in either wheat or barley, when these crops were, respectively, grown year after year on the same land. The greatest yield of nitrogen had been in a clover crop, grown once during the 8 years; and the wheat crops grown after this clover in the first course of 4 years, and after beans in the second course, were about double those obtained when wheat succeeded wheat.

Thus, Cereal crops, grown year after year on the same land, had given an average of about 30 lbs. of nitrogen, per acre, per annum; and Leguminous crops much more. Nevertheless the Cereal crop was nearly doubled when preceded by a Leguminous one. It was also about doubled when preceded by fallow. Lastly, an entirely unmanured rotation had yielded nearly twice as much nitrogen as the continuously grown Cereals.

Leguminous crops were, however, little benefited, indeed frequently injured, by the use of the ordinary direct nitrogenous manures. Cereal crops, on the other hand, though their yield of nitrogen was comparatively small, were very much increased by direct nitrogenous manures, as well as when they succeeded a highly nitrogenous Leguminous crop, or fallow. But when nitrogenous manures had been employed for the increased growth of the Cereals, the nitrogen in the immediate increase of produce had amounted to little more than 40 per cent. of that supplied, and that in the increase of the second year after the application, to little more than one-tenth of the remainder. Estimated in the same way, there had been in the case of the meadow grasses scarcely any larger proportion of the supplied nitrogen recovered. In the Leguminous crops the pro-

portion so recovered appeared to be even less; whilst in the root-crops it was probably somewhat greater. Several possible explanations of this real or apparent loss of the nitrogen supplied by manure are enumerated.

The question arises—what are the sources of all the nitrogen of our crops beyond that which is directly supplied to the soil by artificial means? The following actual or possible sources may be enumerated:—the nitrogen in certain constituent minerals of the soil; the combined nitrogen annually coming down in the direct aqueous depositions from the atmosphere; the accumulation of combined nitrogen from the atmosphere by the soil in other ways; the formation of ammonia in the soil from free nitrogen and nascent hydrogen; the formation of nitric acid from free nitrogen; the direct absorption of combined nitrogen from the atmosphere by plants themselves; the assimilation of free nitrogen by plants.

A consideration of these several sources of the nitrogen of the vegetation which covers the earth's surface showed that those of them which have as yet been quantitatively estimated are inadequate to account for the amount of nitrogen obtained in the annual produce of a given area of land beyond that which may be attributed to supplies by previous manuring. Those, on the other hand, which have not yet been even approximately estimated as to quantity —if indeed fully established qualitatively—offer many practical difficulties in the way of such an investigation as would afford results applicable in any such estimates as are here supposed. It appeared important, therefore, to endeavour to settle the question whether or not that vast storehouse of nitrogen, the atmosphere, affords to growing plants any measurable amount of its *free* nitrogen. Moreover, this question had of late years been submitted to very extended and laborious experimental researches by M. Boussingault, and M. Ville, and also to more limited investigation by MM. Mène, Roy, Cloez, De Luca, Harting, Petzholdt and others, from the results of which diametrically opposite conclusions had been arrived at. Before entering on the discussion of their own experimental evidence, the Authors give a review of these results and inferences; more especially those of M. Boussingault who questions, and those of M. Georges Ville who affirms the assimilation of *free* nitrogen in the process of vegetation.

The general method of experiment instituted by Boussingault,

which has been followed, with more or less modification, in most subsequent researches, and by the Authors in the present inquiry, was—to set seeds or young plants, the amount of nitrogen in which was estimated by the analysis of carefully chosen similar specimens; to employ soils and water containing either no combined nitrogen, or only known quantities of it; to allow the access either of free air (the plants being protected from rain and dust)—of a current of air freed by washing from all *combined* nitrogen—or of a limited quantity of air, too small to be of any avail so far as any compounds of nitrogen contained in it were concerned; and finally, to determine the amount of combined nitrogen in the plants produced and in the soil, pot, &c., and so to provide the means of estimating the gain or loss of nitrogen during the course of the experiment.

The plan adopted by the Authors in discussing their own experimental results, was—

To consider the conditions to be fulfilled in order to effect the solution of the main question, and to endeavour to eliminate all sources of error in the investigation.

To examine a number of collateral questions bearing upon the points at issue, and to endeavour so far to solve them, as to reduce the general solution to that of a single question to be answered by the results of a final set of experiments.

To give the results of the final experiments, and to discuss their bearings upon the question which it is proposed to solve by them.

Accordingly, the following points are considered :—

1. The preparation of the soil, or matrix, for the reception of the plants and of the nutriment to be supplied to them.

2. The preparation of the nutriment, embracing that of mineral constituents, of certain solutions, and of water.

3. The conditions of atmosphere to be supplied to the plants, and the means of securing them; the apparatus to be employed, &c.

4. The changes undergone by nitrogenous organic matter during decomposition, affecting the quantity of combined nitrogen present, in circumstances more or less analogous to those in which the experimental plants are grown.

5. The action of agents, as ozone; and the influence of other

circumstances which may affect the quantity of combined nitrogen present in connexion with the plants, independently of the direct action of the growing process.

In most of the experiments a rather clayey soil, ignited with free access of air, well-washed with distilled water, and re-ignited, was used as the matrix or soil. In a few cases washed and ignited pumice-stone was used.

The mineral constituents were supplied in the form of the ash of plants, of the description to be grown if practicable, and if not, of some closely allied kind.

The distilled water used for the final rinsing of all the important parts of the apparatus, and for the supply of water to the plants, was prepared by boiling off one-third from ordinary water, collecting the second third as distillate, and redistilling this, previously acidulated with phosphoric acid.

Most of the pots used were specially made, of porous ware, with a great many holes at the bottom and round the sides near to the bottom. These were placed in glazed stone-ware pans with inward-turned rims to lessen evaporation.

Before use, the red-hot matrix and the freshly ignited ash were mixed in the red-hot pot, and the whole allowed to cool over sulphuric acid. The soil was then moistened with distilled water, and after the lapse of a day or so the seeds or plants were put in.

Very carefully picked bulks of seed were chosen; specimens of the average weight were taken for the experiment, and in similar specimens the nitrogen was determined.

The atmosphere supplied to the plants was washed free from ammonia by passing through sulphuric acid, and then over pumice-stone saturated with sulphuric acid. It then passed through a solution of carbonate of soda before entering the apparatus enclosing the plant, and it passed out again through sulphuric acid.

Carbonic acid, evolved from marble by measured quantities of hydrochloric acid, was passed daily into the apparatus, after passing, with the air, through the sulphuric acid and the carbonate of soda solution.

The enclosing apparatus consisted of a large glass shade, resting in a groove filled with mercury, in a slate or glazed earthenware stand, upon which the pan, with the pot of soil, &c., was placed. Tubes

passed under the shade, for the ingress and the egress of air, for the supply of water to the plants, and, in some cases, for the withdrawal of the water which condensed within the shade. In other cases, the condensed water was removed by means of a special arrangement.

One advantage of the apparatus adopted was, that the washed air was forced, instead of being aspirated, through the enclosing vessel. The pressure upon it was thus not only very small, and the danger from breakage, therefore, also small, but it was exerted upon the inside instead of the outside of the shade; hence, any leakage would be from the inside outwards, so that there was no danger of unwashed air gaining access to the plants.

The conditions of atmosphere were proved to be adapted for healthy growth, by growing plants under exactly the same circumstances, but in a garden soil. The conditions of the artificial soil were shown to be suitable for the purpose, by the fact that plants grown in such soil, and in the artificial conditions of atmosphere, developed luxuriantly, if only manured with substances supplying combined nitrogen.

Passing to the subjects of collateral inquiry, the first question considered was, whether plants growing under the conditions stated would be likely to acquire nitrogen from the air through the medium of ozone, either within or around the plant, or in the soil; that body oxidating free nitrogen, and thus rendering it assimilable by the plants.

Several series of experiments were made upon the gases contained in plants or evolved from them, under different circumstances of light, shade, supply of carbonic acid, &c. When sought for, ozone was in no case detected. The results of the inquiry in other respects, bearing upon the points at issue, may be briefly summed up as follows:—

1. Carbonic acid within growing vegetable cells and intercellular passages suffers decomposition very rapidly on the penetration of the sun's rays, oxygen being evolved.

2. Living vegetable cells, in the dark, or not penetrated by the direct rays of the sun, consume oxygen very rapidly, carbonic acid being formed.

3. Hence, the proportion of oxygen must vary greatly according

to the position of the cell, and to the external conditions of light, and it will oscillate under the influence of the reducing force of carbon-matter (forming carbonic acid) on the one hand, and of that of the sun's rays (liberating oxygen) on the other. Both actions may go on simultaneously according to the depth of the cell; and the once outer cells may gradually pass from the state in which the sunlight is the greater reducing agent to that in which the carbon-matter becomes the greater.

4. The great reducing power operating in those parts of the plant where ozone is most likely, if at all, to be evolved, seems unfavourable to the oxidation of nitrogen; that is under circumstances in which carbon-matter is not oxidized, but on the contrary, carbonic acid reduced. And where beyond the influence of the direct rays of the sun, the cells seem to supply an abundance of more easily oxidized carbon-matter, available for oxidation should free oxygen or ozone be present. On the assumption that nitrates are available as a direct source of nitrogen to plants, if it were admitted that nitrogen is oxidated within the plant, it must be supposed (as in the case of carbon) that there are conditions under which the oxygen compound of nitrogen may be reduced within the organism, and that there are others in which the reverse action, namely, the oxidation of nitrogen, can take place.

5. So great is the reducing power of certain carbon-compounds of vegetable matter, that when the growing process has ceased, and all the free oxygen in the cells has been consumed, water is for a time decomposed, carbonic acid formed, and hydrogen evolved.

The suggestion arises, whether ozone may not be formed under the influence of the powerful reducing action of the carbon-compounds of the cell on the oxygen eliminated from carbonic acid by sunlight, rather than under the direct action of the sunlight itself —in a manner analogous to that in which it is ordinarily obtained under the influence of the active reducing agency of phosphorus? But, even if it were so, it may be questioned whether the ozone would not be at once destroyed when in contact with the carbon-compounds present. It is more probable, however, that the ozone said to be observed in the vicinity of vegetation, is due to the action of the oxygen of the air upon minute quantities of volatile carbo-hydrogens emitted by plants.

Supposing ozone to be present, it might, however, be supposed to act in a more indirect manner as a source of combined and assimilable nitrogen in the Authors' experiments, namely,—by oxidating the nitrogen dissolved in the condensed water of the apparatus—by forming nitrates in contact with the moist, porous, and alkaline soil—or by oxidating the free nitrogen in the cells of the older roots, or that evolved in their decomposition.

Experiments were accordingly made to ascertain the influence of ozone upon organic matter, and on certain porous and alkaline bodies, under various circumstances. A current of ozonous air was passed over the substances for some time daily, for several months, including the whole of the warm weather of the summer; but in only one case out of eleven was any trace of nitric acid detected, namely, that of garden soil; and this was proved to contain nitrates before being submitted to the action of ozone.

It is not, indeed, hence inferred that nitric acid could under no circumstances be formed through the influence of ozone on certain nitrogenous compounds, on nascent nitrogen, on gaseous nitrogen in contact with porous and alkaline substances, or even in the atmosphere. But, considering the negative result with large quantities of ozonous air, acting upon organic matter, soil, &c., in a wide range of circumstances, and for so long a period, it is believed that no error will be introduced into the main investigation by the cause referred to.

Numerous experiments were made to determine whether free nitrogen was evolved during the decomposition of nitrogenous organic compounds.

In the first series of 6 experiments, wheat, barley, and bean-meal were respectively mixed with ignited pumice, and ignited soil, and submitted for some months to decomposition in a current of air, in such manner that any ammonia evolved could be collected and estimated. The result was, that, in 5 out of the 6 cases, there was a greater or less evolution of free nitrogen—amounting, in two of the cases, to more than 12 per cent. of the original nitrogen of the substance.

The second series consisted of 9 experiments; wheat, barley, and beans being again employed, and, as before, either ignited soil or pumice used as the matrix. In some cases the seeds were submitted to experiment whole, and allowed to grow, and the vegetable matter

produced permitted to die down and decompose. In other cases, the ground seeds, or "meals," were employed. The conditions of moisture were also varied. The experiments were continued through several months, when from 60 to 70 per cent. of the carbon had disappeared.

In 8 out of the 9 experiments, a loss of nitrogen, evolved in the free state, was indicated. In most cases, the loss amounted to about one-seventh or one-eighth, but in one instance to 40 per cent. of the original nitrogen. In all these experiments the decomposition of the organic substance was very complete, and the amount of carbon lost was comparatively uniform.

It thus appeared that, under rare circumstances, there might be no loss of nitrogen in the decomposition of nitrogenous organic matter; but that, under a wide range of circumstances, the loss was very considerable—a point, it may be observed, of practical importance in the management of the manures of the farm and the stable.

Numerous direct experiments showed, that when nitrogenous organic matter was submitted to decomposition in water, over mercury, in the absence of free oxygen, there was no free nitrogen evolved. In fact, the evolution in question appeared to be the result of an oxidating process.

Direct experiments also showed, that seeds may be submitted to germination and growth, and that nearly the whole of the nitrogen may be found in the vegetable matter produced.

It is observed that, in the cases referred to in which so large an evolution of free nitrogen took place, the organic substances were submitted to decomposition for several months, during which time they lost two-thirds of their carbon. In the experiments on the question of assimilation, however, but a very small proportion of the total organic matter is submitted to decomposing actions apart from those associated with growth, and this for a comparatively short period of time, at the termination of which the organic form is retained, and therefore but very little carbon is lost. It would appear, then, that in experiments on assimilation no fear need be entertained of any serious error arising from the evolution of free nitrogen in the decomposition of the nitrogenous organic matter necessarily involved, so long as it is subjected to the ordinary process of germination, and exhaustion to supply materials for

growth. On the other hand, the facts adduced afford a probable explanation of any small loss of nitrogen which may occur when seeds have not grown, or when leaves, or other dead matters, have suffered partial decomposition. They also point out an objection to the application of nitrogenous organic manure in such experiments.

Although there can be no doubt of the evolution of hydrogen during the decomposition of organic matter under certain conditions, and although it has long been admitted that nascent hydrogen may, under certain circumstances, combine with gaseous nitrogen and form ammonia—nevertheless, from considerations stated at length in the paper, the Authors infer that there need be little apprehension of error in the results of their experiments, arising from an unaccounted supply of ammonia, formed under the influence of nascent hydrogen given off in the decomposition of the organic matter involved.

Turning to their direct experiments on the question of the assimilation of free nitrogen, the Authors first consider whether such assimilation would be most likely to take place when the plant had no other supply of combined nitrogen than that contained in the seed sown, or when supplied with a limited amount of combined nitrogen, or with an excess of combined nitrogen? And again—whether at an early stage of growth, at the most active stage, or when the plant was approaching maturity? Combinations of these several circumstances might give a number of special conditions, in perhaps only one of which assimilation of free nitrogen might take place, in case it could in any.

It is hardly to be supposed that free nitrogen would be assimilated if an excess of combined nitrogen were at the disposal of the plant. It is obvious, however, that a wide range of conditions would be experimentally provided, if in some instances plants were supplied with no more combined nitrogen than that contained in the seed, in others brought to a given stage of growth by means of limited extraneous supplies of combined nitrogen, and in others supplied with combined nitrogen in a more liberal measure. It has been sought to provide these conditions in the experiments under consideration.

In the selection of plants, it was sought to take such as would be adapted to the artificial conditions of temperature, moisture, &c.

involved in the experiment, and also such as were of importance in an agricultural point of view—to have representatives, moreover, of the two great Natural Families, the Graminaceæ and the Leguminosæ, which seem to differ so widely in their relations to the combined nitrogen supplied within the soil—and finally, to have some of the same descriptions as those experimented upon by M. Boussingault, and M. G. Ville, with such discordant results.

Thirteen experiments were made (4 in 1857 and 9 in 1858), in which the plants were supplied with no other combined nitrogen than that contained in the original seed. In 12 of the cases prepared soil was the matrix, and in the remaining one prepared pumice.

Of 9 experiments with Graminaceous plants, 1 with wheat and 2 with barley were made in 1857. In one of the experiments with barley there was a gain of 0·0016, and in the other of 0·0026 gramme of nitrogen. In only two cases of the experiments with cereals in 1858, was there any gain of nitrogen indicated; and in both it amounted to only a small fraction of a milligramme. Indeed, in no one of the cases, in either 1857 or 1858, was there more nitrogen in the *plants themselves*, than in the seed sown. A gain was indicated only when the nitrogen in the soil and pot—which together weighed about 1500 grammes—was brought into the calculation. Moreover, the gain only exceeded 1 milligramme in the case of the experiments of 1857, when slate, instead of glazed earthenware stands were used as the lute vessels; and there was some reason to believe that the gain indicated was due to this circumstance. In none of the other cases was the gain more than would be expected from error in analysis.

The result was then, that in no one case of these experiments was there any such gain of nitrogen as could lead to the supposition that *free* nitrogen had been assimilated. The plants had, however, vegetated for several months, had in most cases more than trebled the carbon of the seed, and had obviously been limited in their growth for want of a supply of available nitrogen in some form. During this long period they were surrounded by an atmosphere containing free nitrogen; and their cells were penetrated by fluid saturated with that element. It may be further mentioned, that many of the plants formed glumes and paleæ for seed.

It is to be observed that the results of these experiments with cereals go to confirm those of M. Boussingault.

The Leguminous plants experimented upon did not grow so healthily under the artificial conditions as did the cereals. Still, in all three of the cases of these plants in which no combined nitrogen was provided beyond that contained in the original seed, the carbon in the vegetable matter produced was much greater than that in the seed—in one instance more than 3 times greater. In no case, however, was there any indication of assimilation of free nitrogen, any more than there had been by the Graminaceous plants grown under similar circumstances.

One experiment was made with buckwheat, supplied with no other combined nitrogen than that contained in the seed. The result gave no indication of assimilation of free nitrogen.

In regard to the whole of the experiments in which the plants were supplied with no combined nitrogen beyond that contained in the seed, it may be observed that, from the constancy of the amount of combined nitrogen present in relation to that supplied, throughout the experiments, it may be inferred, as well that there was no evolution of free nitrogen by the growing plant, as that there was no assimilation of it; but it cannot hence be concluded that there would be no such evolution if an excess of combined nitrogen were supplied.

The results of a number of experiments, in which the plants were supplied with more or less of combined nitrogen, in the form of ammonia-salts, or of nitrates, are recorded. Ten were with Cereals; 4 in 1857, and 6 in 1858. Three were with Leguminous plants; and there were also some with plants of other descriptions—all in 1858.

In the case of the cereals more particularly, the growth was very greatly increased by the extraneous supply of combined nitrogen; in fact, the amount of vegetable matter produced was 8, 12, and even 30 times greater than in parallel cases without such supply. The amount of nitrogen appropriated was also, in all cases many times greater, and in one case more than 30 times as great, when a supply of combined nitrogen was provided. The evidence is therefore sufficiently clear that all the conditions provided, apart from those which depended upon a supply of combined nitrogen, were adapted for vigorous growth; and that the limitation of growth where no combined nitrogen was supplied was due to the want of such supply.

In 2 out of the 4 experiments with cereals in 1857, there was a slight gain of nitrogen beyond that which should occur from error in analysis; but in no one of the 6 in 1858, when glazed earthenware instead of slate stands were used, was there any such gain. It is concluded, therefore, that there was no assimilation of free nitrogen. In some cases the supply of combined nitrogen was not given until the plants showed signs of decline; when, on each addition, increased vigour was rapidly manifested. In others the supply was given earlier and was more liberal.

As in the case of the Leguminous plants grown without extraneous supply of combined nitrogen, those grown with it progressed much less healthily than the Graminaceous plants. But the results under these conditions, so far as they go, did not indicate any assimilation of free nitrogen.

The results of experiments with plants of other descriptions, in which an extraneous supply of combined nitrogen was provided, also failed to show an assimilation of free nitrogen.

Thus, 19 experiments with Graminaceous plants, 9 without and 10 with an extraneous supply of combined nitrogen—6 with Leguminous plants, 3 without and 3 with an extraneous supply of combined nitrogen, and also some with other plants, have been made. In none of the experiments, with plants so widely different as the Graminaceous and the Leguminous, and with a wide range of conditions of growth, was there evidence of an assimilation of free nitrogen.

The conclusions from the whole inquiry may be briefly summed up as follows:—

The yield of nitrogen in the vegetation over a given area, within a given time, especially in the case of Leguminous crops, is not satisfactorily explained by reference to the hitherto quantitatively determined supplies of *combined* nitrogen.

The results and conclusions hitherto recorded by different experimenters on the question whether plants assimilate *free* or *un*combined nitrogen, are very conflicting.

The conditions provided in the experiments of the Authors on this question were found to be quite consistent with the healthy development of various Graminaceous Plants, but not so much so for that of the Leguminous Plants experimented upon.

It is not probable that, under the circumstances of the experiments on assimilation, there would be any supply to the plants of an unaccounted quantity of combined nitrogen, due to the influence either of ozone, or of nascent hydrogen.

It is not probable that there would be a loss of any of the combined nitrogen involved in an experiment on assimilation, due to the evolution of free nitrogen in the decomposition of organic matter, excepting in certain cases when it might be presupposed.

It is not probable that there would be any loss due to the evolution of free nitrogen from the nitrogenous constituents of the plants during growth.

In numerous experiments with Graminaceous plants, under a wide range of conditions of growth, in no case was there any evidence of an assimilation of free nitrogen.

In experiments with Leguminous plants the growth was less satisfactory, and the range of conditions was, therefore, more limited. But the results with these plants, so far as they go, do not indicate any assimilation of free nitrogen. It is desirable that the evidence of further experiments with such plants, under conditions of more healthy growth, should be obtained.

Results obtained with some other plants, are in the same sense as those with Graminaceous and Leguminous ones, in regard to the question of the assimilation of free nitrogen.

In view of the evidence afforded of the non-assimilation of *free* nitrogen by plants, it is very desirable that the several actual or possible sources whence they may derive *combined* nitrogen should be more fully investigated, both qualitatively and quantitatively.

If it be established that plants do not assimilate free or uncombined nitrogen, the source of the large amount of combined nitrogen known to exist on the surface of the globe, and in the atmosphere, still awaits a satisfactory explanation.

ON THE APPLICATION OF

DIFFERENT MANURES

TO

DIFFERENT CROPS,

AND ON THEIR

PROPER DISTRIBUTION

ON THE FARM,

BY

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ON THE APPLICATION OF DIFFERENT MANURES TO DIFFERENT CROPS, AND ON THEIR PROPER DISTRIBUTION ON THE FARM.

Introductory Observations.

Under the system of Farming current 30 or 40 years ago, an improper application or distribution of Manure was little likely to take place. Once every 4 or 5 years each field received a share of the home manures—the produce of the stables, and yards—which would not vary much in quantity or in quality, from year to year.

Agriculture as practised by the more advanced Farmers of the present day, differs widely from this routine: various descriptions of purchased Cattle-food, and Artificial Manure, are now largely used. Root-crops are at one time grown by Artificial Manures alone, and at another by dung; they are sometimes all drawn from the land, and at others consumed where they are grown, with Corn or Cake in addition. Light Artificial Manures are used as a top-dressing for Corn in one field, and not in the next. Rich Manure from fattening cattle is made in the boxes and sheds, and a much poorer quality in the yards; and so on.

These comparatively modern practices, although tending to increase the amount of manurial matters on the farm as a whole, frequently lead to a very unequal distribution of them. Hence it may often happen that, whilst the crop in one field may be suffering from a relative deficiency of certain constituents in the soil, these may exist in the adjoining field in relative excess.

The uncertainty of effect often observed in the action of Artificial Manures, is doubtless frequently due to the disturbance of the proper balance of constituents requisite for healthy growth, the result of injudicious management during the previous course of cropping. For instance, how different must be the condition of the land in regard to the immediately available supply of certain mineral constituents, after a root-crop grown by Artificial Manures, and removed for consumption in the yards and feeding sheds, and after one grown by dung and consumed upon the land, with

or without other food in addition! How different must be the action of Nitrate of Soda, or other chiefly nitrogenous manure, upon the succeeding corn-crop in the two cases! It is true, that the field which has suffered this temporary comparative exhaustion, will, under a system of liberal farming, be duly replenished in the course of time. But, on light soils more especially, the injurious influence of such irregular distribution of the constituents of manure, must frequently be felt; and it may sometimes result in serious losses to the Farmer.

It is obvious that the subject of the proper *application*, and *distribution*, of the manures used on a farm, demands very careful consideration.

The constituents of Manure form a part of the floating capital of the farm; but they yield no interest so long as they do not contribute to an increase in the produce of the land. A certain proportion of them enters into the corn and meat which are sold off the farm; another portion remains in the straw and root and fodder crops, in due time to be returned again to the land in the form of manure, and a third portion remains in the soil to be taken up by future crops at a more or less distant period. It is clear that the Farmer should endeavour so to arrange his manuring and cropping, that the greatest possible amount of manurial constituents should be engaged each year in the promotion of vegetable growth; and it is with the view of leading to a more careful consideration of this subject, and of what is necessary to secure the desired result, that I propose to make a few remarks of a practical kind, on both the *application*, and the *distribution*, of manures.

Although the two subjects are very intimately connected, they may with advantage be treated of, to a certain extent, separately. Thus, I propose in speaking of the *application* of manures, to confine attention to the description of manures best adapted to the different crops, and to the best time and mode of their application; and when speaking of their *distribution*, to call attention more especially to the temporary disturbance of the balance, or relative exhaustion of constituents, which is liable to occur under ordinary circumstances on certain portions of the farm, and to the means which the Farmer has at his disposal for insuring a more equal distribution of the constituents circulating on his farm.

ON THE ADAPTATION OF DIFFERENT MANURES TO DIFFERENT CROPS.

Any rational and economical system of manuring must obviously be based upon some knowledge of the effects of the different

descriptions of manure upon the various crops when they are grown in an ordinary course of cultivation.

It is true, that science is not at present able fully to account for the very characteristic and powerful action of certain constituents of manure upon the growth of one description of plant, and not of another. Some writers have therefore denied that such a difference of effect exists. The very different effects of Ammoniacal Salts upon the *Graminaceous* crops (such as Wheat, Meadow Grasses, Rye-grass, &c.) on the one hand, and on the *Leguminous* crops (such as Beans and Clover) on the other, may be taken to illustrate the point. The records of nearly 20 years of experiments at Rothamsted, have not afforded a single instance in which the application of Ammoniacal Salts to a *Cereal* crop has failed to give a greater or less increase of produce. This is the case even where there has been a very unusual exhaustion of mineral constituents; and this effect of Ammoniacal Salts is quite consistent with that observed when such crops are cultivated and manured according to the ordinary course of practice. On the other hand, experiments continued for more than half that period with *Leguminous* crops, such as Clover and Beans, as well as practical experience with such crops, show no such result on the direct application of Ammoniacal Manures. Yet there is a much larger amount of that important element of ammonia —*nitrogen*—in a Leguminous than in a Graminaceous crop.

It is in fact, bad practice to apply Peruvian Guano, or Ammoniacal Salts, to a Bean or a Clover crop; and where Dung is applied both to the Wheat and Bean crops, true economy would suggest that the rich oil-cake dung be employed for the Wheat, and that which is poorer for the Beans and Clover.

Supposing, instead of this, 10 tons of rich dung containing 0·8 per cent. Nitrogen (equal to nearly 1 per cent. of Ammonia) were applied in the Autumn to an acre of Clover to be mown the following year, and 10 tons of poor dung containing only half that amount of nitrogen were applied per acre for the growth of Wheat, the Clover would be manured with about 180 lbs. of Nitrogen, equal to about 218 lbs. of Ammonia, and the Wheat with only about 90 lbs. of nitrogen equal to about 109 lbs. of Ammonia. The Nitrogen or Ammonia, applied to the Clover has comparatively little effect upon either the quantity or the quality of the produce; and as Ammonia is worth about 8d. per lb. there is, of course, in the case of such manuring, a very unprofitable outlay of capital. If, on the other hand, the rich dung had been applied to the

Wheat crop, the additional 90 lbs. of nitrogen, equal to 109 lbs. Ammonia, would probably add many bushels of corn, and cwts. of straw, to the produce of the immediate crop.

Upon all the lighter descriptions of soil where experience has established that it is advantageous to use dung for Wheat, the best qualities of it should be devoted to that crop. Upon the heavier descriptions of soil the best dung should be applied to the Mangold crop: in the following list the crops are arranged in something like the order in which they stand to one another, in regard to the quality of dung they respectively require, considering Wheat as requiring the best :—

Wheat
Mangolds
Swedes
Common Turnips
Tares
Beans
Clover

It would be impossible to define the exact qualities of land on which it is advisable to employ dung for the Wheat crop. The experience of the district is generally a pretty good guide. It is, however, only upon the lighter soils that the practice prevails. On the majority of the soils of this Country, the dung can be applied to greater advantage to other crops, particularly to the Roots ; and when this is the case, the Wheat crop may be grown by the aid of Artificial Manures, of which Peruvian Guano is the best for the purpose. Where Roots are grown upon heavy land, one of the beneficial effects of the use of dung is that of lightening the soil. For the Leguminous crops (Beans, Tares, and Clover) no Artificial Manure can be recommended.

There are some crops which it may be said are hardly worth growing unless they can be manured with dung. These are Mangolds, Beans, and Tares. Other roots than Mangolds may be grown by Artificial Manures when they follow closely on a dunged crop. Mangolds should almost always receive the best dung of the farm. Beans and Tares may be manured with inferior qualities of dung. When these crops are not grown, the Swedes and Clover should receive the remainder of the dung; that of the best quality going to the Swedes.

The following Table shows which of the most important crops, may, according to circumstances, be manured either with dung,

or with Artificial Manures in addition, or as substitutes for dung, and also those which cannot with advantage be manured with Artificial Manures :—

Wheat	Dung	or	Artificial
Barley	Dung	...	Artificial
Oats	Dung	...	Artificial
Mangolds ...	Dung	...	Artificial
Swedes	Dung	...	Artificial
Common Turnips ...	Dung	...	Artificial
Potatoes	Dung	...	Artificial
Tares	Dung		
Beans	Dung		
Clover	Dung		
Peas	Dung		

A few observations may now be offered on the nature of the *Artificial* Manures most suited to the different crops, and on the best time and mode of their application.

It will, of course, be perfectly understood, that in giving any advice on the use of Artificial Manures, it is pre-supposed that a Rotation of crops is followed ; that the green crops are consumed upon the farm, and the straw of the corn-crops also retained, yielding manure for return to the land. In fact, if the root-crops, hay, and straw, were taken to Market, and adequate restoration not made by means of stable and other town manures, the ordinary Artificial Manures which are found to have such beneficial effects under existing circumstances, would then be of very little value.

Peruvian Guano, Nitrate of Soda, Sulphate of Ammonia, and Superphosphate of Lime, are the most important Artificial Manures ; and used either separately or in combination, in the majority of cases supply what is necessary in addition to the home manures to obtain luxuriant crops. Other Artificial Manures are either so uncertain in their action, or only locally useful, or are so limited in quantity and high in price, as to render a consideration of them unimportant for our present purpose.

WHEAT.

On the heavier descriptions of land, 2 to 3 cwts. per acre, of Peruvian Guano, is the best manure for this crop. It should be sown broad-cast before the seed, and harrowed in. It is sometimes mixed with twice its weight of common salt, by which, as well as by ashes, or other matters, a more equal distribution through the soil is attained.

BARLEY AND OATS.

When either of these crops follows a Root-crop which has been partially or wholly removed from the land, a mixture of equal parts Peruvian Guano, or Nitrate of Soda, or Sulphate of Ammonia, and Superphosphate of Lime, may be used with advantage. The selection of one or other of the three Nitrogenous Manures mentioned, should depend in some measure upon the comparative cost of each at the time. About 1 cwt. of the Guano, Nitrate, or Sulphate, and 1 cwt. of Superphosphate of Lime, will generally be sufficient for an acre. The manure should be sown before the seed, as recommended for Wheat. When one corn-crop follows another, as Oats after Wheat, about twice as much of the Artificial mixture should be used as under ordinary circumstances. When corn-crops require to be top-dressed late in the Spring, Nitrate of Soda is the best manure to employ; 1 to 1½ cwt. per acre, being used.

MEADOW HAY.

To Grass-land mown for Hay, from 8 to 10 tons of rotten dung should be applied once in about every 4 or 5 years, in the month of November. The Artificial Manures most suitable for Grass-land, are, Peruvian Guano, Salts of Ammonia, and Nitrate of Soda. When either of these manures is used alone, the following quantities may be applied :—

Peruvian guano	2	to	2½	cwts. per acre.
Salts of ammonia	1	„	1½	„ „
Nitrate of soda	1	„	1½	„ „

One cwt. of Nitrate of Soda, mixed with one cwt. of Superphosphate of lime, is also a very good manure. Or, a mixture of equal parts of Peruvian Guano, Ammonia Salts, Nitrate of Soda, and Superphosphate of Lime, applied at the rate of two cwts. per acre, is perhaps the most generally useful. In deciding upon the exact combination to be employed, some regard should be had to the relative cost of the several substances at the time, as it varies considerably from season to season.

The best time to apply the Artificial Manures is from the end of January to the middle of February; if the application is delayed much later than this, Nitrate of Soda is the best manure to employ.

MANGOLD WURTZEL.

This crop requires to be very liberally manured. The best dung at command should be employed; 10, 15, or even 20 tons per acre, being spread after the land is drawn in ridges, and previous to their being split; and 2 to 3 cwts. of Peruvian Guano mixed with

twice its weight of common salt, should be strained by hand on the top of the dung. Common salt appears to act more beneficially as a manure for Mangolds than for any other crop of the farm ; it also produces marked effects upon the growth of Asparagus in our gardens. Both plants are in fact indigenous to the sea coast.

TURNIPS.

When Swedes, or common Turnips, follow a corn-crop which had been manured by farm-yard dung, the roots may be grown by Artificial Manures alone. From 2½ to 3 cwts. of Superphosphate of Lime should be drilled with the seed ; and in the case of Swedes (excepting when sown late, or the land be considered in good condition) from 2 to 3 cwts. of Peruvian Guano may be used in addition. If the preceding crop has not been manured by dung, 7 to 10 tons per acre, should be applied ; 2½ cwts. of Superphosphate of Lime being drilled with the seed ; and if the dung used be poor, 2 cwts. of Peruvian Guano may be strained over it in the drills. Or, where no manure-drill is employed, the Superphosphate of Lime may be sown broad-cast after the dung is spread, either alone, or mixed with guano, as the case may require. These manures do not re-act injuriously upon each other when mixed together ; but the guano is liable to be injurious to the young Turnip plant if brought in close contact with it. Hence, when guano and Superphosphate of Lime are mixed together, and sown by the drill, 2 or 3 inches of soil should intervene between the manure and the seed.

Bone dust, and its modern ally Superphosphate of Lime, are the staple Artificial Manures for the Turnip crop. In the latter manure, a vast quantity of Mineral Phosphates, which are quite worthless as manures in their natural condition, are rendered soluble by the addition of Sulphuric acid ; and when applied to the land so prepared, they are readily taken up by the roots of the plant. Much manure is now made from *burnt* bones, and is called *Bone Superphosphate ;* but such manure possesses no higher value than Superphosphate made from mineral phosphate. Superphosphate made from common *un-burnt* bones has, however, a much higher value. But un-burnt bones and Sulphuric Acid alone, will not make a manure sufficiently dry to be packed in bags, or to be applied by the drill. It is necessary, therefore, when bones are used for making Superphosphate, to mix them with a certain portion of mineral phosphates, and a manure so made is superior to any other for the Turnip crop.

On many soils the decomposition of common bone-dust does not take place quickly enough for the Turnip crop. But on those in

which the action is sufficiently rapid, the preference should be given to Bones rather than to Superphosphate, when they can be purchased at a moderate price; though when they become dear, which generally happens every 4 or 5 years, a change to Superphosphate of Lime would be desirable.

Whilst on the subject of Turnips, a few observations may be made on the increasing tendency of the crop to decay of late years. This is supposed by many to be in some way connected with the extensive use of Artificial Manures for the growth of the crop. The three conditions under which the decay of the roots is most likely to take place are—

1. When they contain a large proportion of water.
2. When the bulb is large.
3. If the bulbs are too ripe when the growth is arrested by Winter.

From the results of experiments conducted at Rothamsted for many years, it does not appear that the proportion of water in the Turnip is increased by the use of Artificial Manures. Some of the descriptions of Turnips of comparatively modern introduction do, however, contain a higher per-centage of water than some of the older sorts. An examination made here showed, that whilst the old purple top Swede contained about 12¼ per cent. of dry substance, the green and purple top Skirving's did not contain quite 9½ per cent. It would be expected that, with such a marked difference as this in the amount of dry matter, there would be a great difference in the power of resisting changes of temperature; and it seems to be generally admitted that the Skirving's Swede will decay under circumstances in which some other descriptions will remain sound.

It appears to be a recognized fact that large roots are more liable to decay than smaller ones; and inasmuch as Artificial Manures tend to increase the size of the roots, they may be said, in this sense, *indirectly* to injure their keeping properties; and especially so if the Artificial Manures employed are such as tend to induce early maturity, as well as great size.

When Turnips arrive at maturity before the cold weather sets in, they have less power to resist the attacks of frost than roots which are immature and still in a growing state. In regard to keeping properties, the ripe Turnip may be compared to apples or pears which are fit for the table in the Autumn, and the less ripe one to fruit of the same description which only becomes ripe after it

has been gathered for some time. Our experiments show that not only the size and quality of the Turnip, but the period at which it will reach a given point of maturity, is very greatly influenced by the kind of Artificial Manure employed. Seed sown on the same day will yield Turnips, at a given period in the Autumn, in a perfectly mature condition, and in various stages approaching maturity, according to the description of manure. The so-called Mineral Manures, of which Superphosphate of Lime is the most important in use for the crop, bring the plant to early maturity. Nitrogenous Manures on the other hand, tend to retard maturity.

When Turnips are required for early Autumn food, they should be sown early, and Superphosphate of Lime should be drilled with the seed. Besides the effect of Superphosphate of Lime in rapidly developing the young plant, and hence frequently securing the crop, its influence in hastening maturity also enables the Farmer, by its use, to sow later than he otherwise could do, and thus to devote a longer period of time to the tillage of his land. Early sown Turnips required for feeding later, or to stand the Winter, should have their growth prolonged by the use of a larger proportion of Nitrogenous Manures, such as Peruvian Guano, provided the Dung employed be not rich enough to carry the crop.

POTATOES.

The amount of Mineral matter in the acreage produce of a root crop, is very large indeed compared either with that in the meat produced by its consumption, or in the portion of a corn-crop usually taken to market. Hence, when a root-crop is sold, there should be a restoration of mineral matter from some source external to the farm itself. The following statement of the amount of mineral matter contained in a moderate crop of Wheat-grain and of Potatoes, will illustrate the point—

	Mineral Matter.
28 Bushels of Wheat-grain ...	... 28 lbs.
8 Tons of Potatoes	... 180 „

Of Potash alone, the 8 tons of Potatoes will contain about 8 times as much as the 28 bushels of Wheat. The Salts of Potash are, however, very high in price. In fact it would not be economical to restore the whole of the mineral constituents of the Potatoes in the form of the so-called artificial manures. For this reason, and also for the restoration of organic substance, it is necessary, whenever roots, hay, or straw, are extensively sold, to bring upon the farm some of the more bulky manuring matters which the locality affords; such as stable dung, or other town manures, sea-weed, or even fern or brake from neighbouring wastes, for

litter. The exhaustion by the sale of Potatoes may be compensated for by bringing upon the farm a sufficient quantity of any of the manuring matters just mentioned.

It is the general practice to dung heavily for Potatoes. Although the crop might not be so large, it is probable that if Potatoes were taken after some other crop well dunged, instead of the Dung being applied directly for their growth, they would be less liable to disease. Supposing this plan adopted, 3 to 4 cwts. per acre, of an equal mixture of Peruvian Guano and Superphosphate of Lime should be used for the Potatoes. Or, in case of dung being employed, the best mode of application would be to plough it into the land in the Autumn, the Potatoes being set in the following Spring.

From the whole of the above remarks upon the manuring of the different crops it will be obvious, that the so-called *Artificial* Manures should only be looked upon and used as aids to the more natural manures of the farm. It will be obvious too, that when the sale of Hay, Straw, Potatoes, or Roots, constitutes a prominent part of the practice of the farm, adequate restoration should be made by means of other manures than those which are usually called "Artificial," from some source external to the ordinary resources of the farm.

As this paper may perhaps find its way into the hands of some who are interested in the cultivation of the Hop, or Sugar cane, a few observations may be made as to the manures required for these important crops.

HOPS.

In order to cultivate the Hop with success, it is necessary to manure liberally with the bulky animal and vegetable manures. The light Artificial Manures, which can frequently with advantage be used alone for some of the crops of an ordinary rotation, when others grown in alternation with them are well dunged, should only be used in conjunction with the more bulky manures in the cultivation of the Hop.

Dung, woollen rags, shoddy, skin clippings, and the like, are all valuable manures for the Hop; and one or more of these should always be liberally employed for this crop. In farm-yard dung, the proportions of Mineral matter, and of Organic matter yielding Carbonic Acid and some other Organic compounds in the soil, are comparatively large; but the amount of Nitrogen or Ammonia-

yielding matter is small. With this manure there should, therefore, also be employed woollen rags, shoddy, or skin clippings, which are rich in Ammonia-yielding substance, but poor in Mineral matter. Rape cake is also an exceedingly good manure for Hops. Peruvian Guano may also be used with advantage, in addition to, but not as a substitute for, the more bulky manures.

Besides the above named manures, some of which may be considered as essential to the successful cultivation of the Hop, more attention should be paid to the application of top-dressings of Soluble Nitrogenous Manures late in the season, than has hitherto been devoted to it. I was engaged in a series of experiments with different manures on the Hop, with the late Mr. PAINE, of FARNHAM, the results of which promised to be of great value; but, unfortunately, the continuance of them was prevented by his illness and death. It was found that the application of 3 or 4 cwts. of Sulphate of Ammonia, per acre, in the month of July, produced most striking effects. In some instances all disease was arrested, and a large crop of Hops obtained from bines which, to all appearance, would have produced a very small one without the top-dressing. It is very desirable that further trials with Salts of Ammonia, top-dressed at the period of growth above referred to, should be made.

THE SUGAR CANE.

The Sugar Cane is a member of the same great botanical family, to which our cultivated grain-crops belong. It is found that with these (provided that the soil supply a sufficiency of the mineral constituents) the amount of carbon fixed by the plant, depends very materially on the amount of available nitrogen within the soil. In the absence of direct experiment, there are reasons for supposing that the result would be very similar with the Sugar Cane; though, under a tropical sun, the amount of carbon fixed, under otherwise equal circumstances, is very much greater.

Sugar, a compound containing neither mineral matter nor nitrogen, and deriving its constituents largely from the atmosphere, is the only necessary export from the plantation. The amount of mineral matters removed from the land in the crop is undoubtedly large; but they should not be ultimately lost to the soil. The whole of these constituents should be found in the ashes of the stoke-hole where the cane is burnt, and they should be carefully collected and returned to the land. A little Phosphate, in the rapidly acting condition of Superphosphate of Lime, is probably the only additional mineral manure that would be required. Provided the supply of mineral constituents be kept up as here supposed, it is not easy to

see why perfect fertility might not then be maintained by means of a due supply of nitrogenous manures.

On the grounds above suggested, I should recommend as an Artificial Manure for the Sugar Cane, a mixture of about 1 cwt. of Superphosphate of Lime, and 3 to 5 cwts. of Sulphate of Ammonia, per acre; or Peruvian Guano, in amount equal to the same money value. Each hill of Canes should receive its measured quantity, which should be hoed under the soil as quickly as possible, either immediately before, or during the rainy season.

Nitrate of Soda, and muriate of ammonia, would probably act as well as Sulphate of Ammonia, in increasing the growth of the Cane but it is to be feared that, with their use, the juice would be more likely to contain saline matters which would interfere with the proper crystallization of the Sugar.

In thus recommending only Sulphate of Ammonia and superphosphate of Lime, or Peruvian Guano, as the Artfiicial Manures for the Sugar Cane, it must be clearly understood, that this is only on the supposition that the mineral matters of the removed crop, are duly returned to the land. If Sulphate of Ammonia be used without attending to this precaution, a continued beneficial result cannot be expected, any more than were it employed for the corn crops grown in our rotations, without observing the ordinary conditions of such growth. These conditions are the systematic periodical return to the land of by far the greater part of the mineral matters of the crops (with perhaps those of purchased cattle food also), by means of the home Manures; and, when Artificial Nitrogenous Manures are purchased, the almost invariable practice is to import Phosphatic Manures in addition.

ON THE UNEQUAL DISTRIBUTION OF MANURES ON THE FARM.

From the subject of the adaptation of different manures to different crops, I now turn to that of their distribution over the farm. It is not my intention to enter at all fully into this question; or to lay down specific rules in regard to it, for application in practice. What I propose to do is, simply to call attention to one or two illustrations of the unequal distribution of the manures over the farm, such as may easily occur in the ordinary course of practice; and to supply a Table, which will be found at the end of this Paper, showing the average composition of different kinds of agricultural produce, &c., by means of which any thoughtful and intelligent Farmer will be enabled to work out for himself, what his own practice requires.

It is a matter of common experience in farming, that the same and, manured in the same way, will yield very different amounts of produce in different years, according to the characters of the season in regard to heat and moisture. I will take an example from my own farm.

The Mangold crop was manured in the same way in 1859, and in 1860. A portion of the crop of 1859 was weighed, and the result indicated an average of 49 tons of Roots per acre. The crop of 1860 was not weighed; but it was estimated at less than half that of 1859. For the sake of argument, we will suppose it to be one-half, and the per-centage composition of the crop (which would not differ sufficiently to affect the question) to be the same in the two cases. Both crops being removed from the land, it is obvious, that the soil which was in both cases manured to carry the whole course, was deprived of twice as much of certain constituents by the first crop of the rotation—the Mangolds—in the one case as in the other. It would, therefore, be in very different condition for succeeding crops in the two cases, in regard to the immediately available supply of those constituents.

Thus, estimating the Nitrogen in the fresh Mangolds at 0·25 per cent., and the total Mineral matter at 1 per cent., there were removed per acre—

	Nitrogen.	Total Mineral matter.
In the Mangold crop of 1859 .	274 lbs.	1098 lbs.
In the Mangold crop of 1860 .	137 „	549 „
More in 1859 than in 1860 .	137 „	549 „

It may be asked, whether, in the majority of cases, any further attempt would be made to equalize the condition of these two fields for the growth of the succeeding crops of the course, than by the application of some light Artificial Manure, rich in Nitrogen, to the Corn crops?—which, if it gave an increase of produce, would further disturb the equilibrium, so far as the mineral constituents not supplied by the Artificial Manure, were concerned.

On the supposition that the 137 lbs. more nitrogen taken off in the larger crop of Mangolds than in the smaller, was derived from the Manure and the soil, it would require 10 or 12 tons of Dung of medium quality for its restoration; or, for the restoration of the extra amount of Potash taken from the land, it would require nearly the same amount of Dung.

On the assumption that the course of Rotation was Mangolds, Barley, Leguminous crop, and Wheat, the extra drain of mineral

constituents by the removal of the larger crop of Mangolds, would be best compensated by the application of Dung for the Leguminous Crop following the Barley.

To take another case of the unequal distribution of manuring matters over the farm: Suppose Turnips to be manured in one field with 2 cwt. of Peruvian Guano and 2 cwts. of Superphosphate of Lime, and in another with 10 tons of Dung; that in both cases half the crop of Swedes is drawn off; Barley following without manure; then Clover mown for Hay; and lastly, Wheat following the Clover. For simplicity of illustration I will suppose the amounts of the corresponding crops be the same throughout the two courses commencing with this irregularity; though, in the case of light soils, of land in poor condition, or of bad seasons, the evil effects would probably be observed in the immediately succeeding crops.

The following statement will show roughly the difference in the condition of the two fields in regard to the amount of *total* mineral matter dependent on the kind of manure supplied to carry the course.

	Swedes manured with 10 tons Dung; containing 3¼ per cent. mineral matter.*		Swedes manured with 2 cwt. Peruvian Guano, and 2 cwt. Superphosphate of Lime.	
Mineral Matter supplied in Manure		784		216
Mineral Matter removed in—				
8 tons of Swedes	90	...	90	...
40 Bushels of Barley, and Straw	170	...	170	...
2 tons of Clover Hay . . .	336	...	336	...
30 Bushels Wheat, and Straw	180	...	180	...
	776	784	776	216
		776		776
		Gain 8		Loss 560
				8
Difference between the two fields			... ...	568

Thus, under the circumstance supposed, where the Dung was supplied for the Swedes; there was a gain of 8 lbs. of mineral matter at the end of the course; but where the Artificial Manures were used, the land was poorer by 560 lbs. of mineral matter. There was, therefore, a difference in the condition of the land in the two cases, at the end of 4 years, amounting to 568 lbs. of mineral matter, depending on the different method of manuring. It must be further remembered, that in the Dung a great variety of mineral constituents would

* Fresh *undecomposed* Dung, will probably seldom contain much more than 3 per-cent. of mineral matter *exclusive of dirt*; but after Dung has lost organic matter by rotting, the per-centage will be higher.

be supplied, and pretty nearly in the proportion in which they would be required by the crops; whereas, in the Artificial Manures, this would not be the case. It is obvious, that the field manured with only Artificial Manure for the Swedes, should receive a much heavier dressing of Dung for the succeeding course, than the other.

Numerous other cases of disturbance might be supposed. For instance, in the case of the land manured with farm-yard dung, the Clover might be grazed instead of mown and removed as Hay, and then the balance between the two fields would be still further thrown out. But the illustrations given will perhaps be sufficient to impress upon the mind of the intelligent Farmer, the importance of carefully arranging his practice so as to prevent, as far as possible, any such unequal distribution over his farm of the manures at his command.

FARM-YARD MANURE.

Farm-yard manure is generally looked upon as the natural manure of our crops. Artificial Manures, on the other hand, are frequently supposed to be mere stimulants; and the very fact that but a small quantity of them may produce as much increase of crop as a very large quantity of farm-yard manure, is brought as an argument against the use of the Artificial Manures. It will not be out of place to conclude with a few observations upon the sources, and the composition, of farm-yard manure.

It is well-known, that the straw of our corn-crops, and the solid and liquid excrements of horses and other animals fed in the stables, sheds, and yards, are the substances which contribute to form the heterogeneous mass called *farm-yard dung*. Let us estimate what proportion of these various matters will, under given circumstances, be included in the complex mass; and thence endeavour to arrive at some conclusion as to its composition.

Suppose the case of a farm of 400 acres, farmed on the 4 course system: that half of the roots, and 100 tons of Hay, are consumed at the homestead; and that the whole of the straw of the corn-crops is retained at home as food and litter. Let it further be assumed that 12 horses have corn equal to 10 lbs. of Oats per head per day; and that about 10 shillings per acre are expended in the purchase of Cake for feeding stock. Under these circumstances, the following would be the amounts of the matters enumerated, entering into the home manures of the farm in the course of the year.

	Total Dry Matter.	Total Mineral Matter. (ash)	Phosphoric Acid, reckoned as Phosphate of Lime.	Potash	Nitrogen.	Nitrogen calculated as Ammonia.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
100 acres roots; half the crop=6 tons per acre, consumed at home, give as Manure	29568	7741	1686	2411	2512	3050
100 acres Barley, at 2500 lbs. straw per acre; 1-5th reckoned as food, and 4-5ths as litter, give as Manure	198333	11138	916	1574	1213	1473
100 tons of Hay consumed at home, give as Manure	94080	14818	2267	3124	3808	4624
100 acres of Wheat; at 3000 lbs. straw per acre; 1-5th reckoned as food, and 4-5ths as litter, give as Manure	235200	14850	1634	1948	1746	2120
Corn=43800 lbs. of Oats, consumed by horses, give as Manure	7534	1198	487	216	745	905
20 tons of Oil Cake (Linseed, Rape, and Cotton Seed), consumed at home, give as Manure	9930	3295	2507	963	2185	2653
Total	574645	53040	9497	10236	12209	14825

These are, as nearly as can be reckoned, the average amounts of the constituents enumerated, that would contribute to the home manure of the farm annually. But farm-yard manure, in the fresh state, and before it has undergone much decomposition, contains about 70 per cent. of water, or 7 parts of water to 3 parts of dry matter. The 574,645 lbs. of dry matter, would thus be combined with 1,340,838 lbs. of water, making together 1,915,483 lbs.=855 Tons (or an aver-

age of about 8½ Tons for each of the 100 acres of Root-crop), of *fresh un-decomposed dung*. In this state, its composition, per cent., and per ton, would be as follows :—

	Total Dry Matter.	Total Mineral Matter.	Phosphoric Acid, reckoned as Phosphate of Lime.	Potash.	Nitrogen	Nitrogen calculated as Ammonia
per cent.	30·0	2·77	0·50	0·53	0·64	0·77
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
per ton.	672	62·0	11·1	12·0	14·3	17·3

This is the composition of the fresh un-decomposed dung calculated from the average composition of the matters which are supposed to enter into it.

The proportion of total *Dry Matter* given above, is rather higher than the average of results obtained at Rothamsted with good box dung; it is also higher than the average of the results given by BOUSSINGAULT; but is lower than the amount given by PROFESSOR VOELCKER for fresh dung.

The amount of *Mineral Matter* found by analysis in farm-yard manure, is generally at least once-and-a-half or twice as much, as that contained in the clean food and litter, owing to the admixture of dirt. The amount of Mineral matter in *fresh* dung due to the Mineral constituents of the food and litter, will probably seldom be much more than 3 per cent.; but in rotten dung that has not wasted by drainage, it may be considerably more.

The calculated amount of *Nitrogen* given above, is almost exactly the mean of the results of BOUSSINGAULT and VOELCKER, on fresh dung; but it is rather less than has been found at Rothamsted in good box-dung.

But farm-yard manure undergoes very considerable diminution by decomposition; and especially when carted out and formed into clamps. Hence, the land would not receive so large a quantity of matter as has been above estimated. The amount of organic matter diminishes very considerably; and in rotten dung the proportion of water is generally higher than above supposed. It also too frequently

happens that both Mineral matter and Nitrogen are allowed to go to waste by drainage, or other mismanagement. Otherwise, as the organic matter diminishes, the amount both of Mineral matter, and of Nitrogen, should increase in proportion to a given weight of the manure.

The composition and value of the manure is also very dependent upon the quality of the food consumed by the animals that help to produce it. Thus, if the same amount of dung had been produced from the same materials above-mentioned, *excluding the 20 tons of Oil Cake*, the yard of manure would have contained 2185 lbs. less of nitrogen, equal to 2653 lbs., or considerably above a ton, less of ammonia ; and every ton of the dung would have contained nitrogen equal to only about 14¼ instead of about 17¼ lbs. of ammonia. In the one case the dung would be called poor, and in the other the Farmer might congratulate himself on having a yard of moderately good dung. Yet the whole weight of dry substance added by the Oil Cake to each ton of dung, would only be about 11 lbs. !—a quantity which is so small that neither the man that loaded the cart, nor the horse that drew the dung to the field, would detect it. If 40 tons instead of 20 tons of Oil Cake had been employed with the same amount of litter, only about another 11 lbs. of dry substance would be added to each ton of the manure, but the yard of manure would then be equal in quality to rich box-dung. In fact, the consumption of £400 worth, or about 40 tons of Cake, would only add about 10 tons of dry substance to the manure heap ; whilst the weight of Peruvian Guano obtained for the same money, would be about 30 tons.

It is quite immaterial to the growth of the crops, whether the additional amount of nitrogen be purchased in the form of Oil Cake, and so supplied to the land in the farm-yard manure, or whether it be purchased and applied in the form of Artificial Manure, provided only that the requisite mineral constituents are not wanting. It is also a matter of indifference to the crops, whether the necessary mineral constituents are supplied in the form of the excrements of animals, or of Artificial Manures. The question is entirely one of economy, depending chiefly, on the relative prices of meat and corn, and of cattle foods and Artificial Manures.

RIOUS KINDS OF

s. Per Ton.

Phosphoric acid, reckoned as Phosphate of Lime.	Potash	Nitrogen
110·2	37·0	106·4
156·8	70·0	145·6
128·8	39·4	112·0
75·7	30·7	85·1
49·3	28·4	89·6
41·2	21·5	76·2
36·5	14·8	94·1
42·3	21·5	96·3
117·1	47·5	94·1
		28·0
25·3	7·8	40·3
42·0	11·2	40 3
30·2	12·3	35·8
35·8	14·6	38·1
26 2	11·2	44·8
144·2	32·7	58·2
168·4	33·4	57·8
178·1	32·5	57·1
28·0	29·1	56·0
19·7	33·6	33·6
20·2	24·9	20·2
19·0	19·9	
12·3	14·6	13·4
8·3	14·1	11·2
10·7	20·8	13·4
2·0	5·6	5 6
2·9	4·0	4·9
2·5	6·5	4·0
7·2	9·6	7·8
2·9	5·1	4·5
9·4	8·1	4·9



From the REPORT *of the* BRITISH ASSOCIATION *for the* ADVANCEMENT *of* SCIENCE *for* 1861.

ON SOME POINTS IN CONNEXION WITH THE EXHAUSTION OF SOILS.

By J. B. LAWES, F.R.S., F.C.S.,
AND
Dr. J. H. GILBERT, F.R.S., F.C.S.

Abstract.

The question of the exhaustion of soils was one of peculiar interest at the present time, not only on account of the great attention now paid to the waste of manuring matters by the discharge of the sewage of towns into our rivers, but also from the fact that Baron Liebig has recently urged that our soils are suffering progressive exhaustion from this cause, and predicted certain, though it may be distant, ruin to the nation, if our present modes of procedure be persevered in.

The question was one of chemical facts; and the authors had intended to treat it much more comprehensively than they were able to do on the present occasion. They proposed, by way of illustration, to bring forward one special case of progressive exhaustion, occurring in the course of their own investigations; and then to contrast the conditions of that result with those of ordinary agriculture.

They had grown wheat for eighteen years consecutively on the same land, respectively without manure, with farm-yard manure, and with different constituents of manure, and they had determined the amounts of the different mineral constituents taken off in the crop from the respective plots. Numerous Tables of the results were exhibited.

The variations in the composition of the ash of both grain and straw, dependent on variations of season, and consequent character of development and maturity, were first pointed out. The general result was, that, with an unfavourable season, there was a slight though appreciable decrease in the percentage of lime and potass, and increase in that of magnesia; and again, an increase in the percentage of phosphoric acid and of silica; and, especially in the case of the straw-ash, a decrease in that of sulphuric acid.

Turning to the bearing of the results on the main subject of inquiry, it appeared that when ammonia-salts were used alone, year after year, on the same land, the composition of the ash, both of grain and straw, showed an appreciable decline in the amount of phosphoric acid, and that of the straw a considerable reduction in the percentage of silica.

When ammonia-salts alone were used, the amount of mineral constituents in the crop of a given area of land was very much increased—much more so than when a liberal supply of mineral constituents alone was used. But in neither of these cases was there anything like the amount of mineral constituents obtained in the crop, that there was when the ammonia-salts and mineral manures were used together, or when farm-yard manure was employed. The greatest deficiency indicated was in the silica and the phosphoric acid, and next in order came potass and magnesia. The exhaustion here apparent was, however, not to be wondered at, when it is considered that, in these experiments in which both corn and straw were annually removed without the usual periodical return of farm-yard manure, there had been on the average annually taken from the land by the use of ammonia-salts about twice as much phosphoric acid, about five times as much potass, and about twenty-five times as much silica, as would be removed under a system of ordinary rotation with home manuring, and selling only corn and meat; in fact, in sixteen years there had been taken from the land as much phosphoric acid as would require thirty-two years, as much potass as would require eighty-two years, and as much silica as would require 400 years of such ordinary practice to remove.

Again, the authors estimated that in the experiments of the Rev. Mr. Smith of Lois Weedon, on the growth of wheat year after year on the same land, without manure, there had been an annual extraction from each acre of land of about three and a half times as much phosphoric acid, about seven times as much potass, and about thirty-seven times as much silica, as there would be in the ordinary course of practice; yet, after some fifteen years, the crops at Lois Weedon were said not to be at all failing.

The authors did not recommend such exhaustive practice as that quoted from their own or the Rev. Mr. Smith's experiments. But the instances given showed the capabilities of certain soils; and in one case the conditions under which the point of comparative exhaustion had been reached. It was of course impossible to state the limits of the capability of soils generally, so infinitely varied was their composition; but it would be useful to give an illustration on this point. Reckoning the soil to be one foot deep, it was estimated that it would require, of ordinary rotation with home manuring and selling only corn and meat, about 1000 years to exhaust as much phosphoric acid, about 2000 years to exhaust as much potass, and about 6000 years to exhaust as much silica, as, according to the average results of forty-two analyses* relating to fourteen soils of very various descriptions, had been found to be soluble in dilute hydrochloric acid. Many soils had, doubtless, a composition inferior to that here supposed. In a large proportion, however, the amounts of the above constituents assumed to be soluble in dilute hydrochloric acid would probably be available for plants long before the expiration of the periods mentioned; whilst, in a large proportion, there would still be further stores eventually available within a greater or a less depth from the surface.

But the exhaustion of mineral constituents by the sale of corn and meat alone was in reality not so great, in the ordinary practice of this country, as has been assumed for the purpose of the above illustrations. Where there was no purchase of cattle-food, or of artificial or town manures, the sales of corn and meat would on the average be much less than were taken in the authors' estimates; and where such materials were purchased with any degree of judgment in the selection, there would always be much more phosphoric acid (otherwise the most easily exhausted constituent) so brought upon the land, than would be obtained from it in the increase of produce yielded; in fact, under such conditions, in many soils potass was more likely to become deficient. Again, by no means the whole of the mineral constituents sent from the farm in the form of corn and meat will reach the sewers of our towns, and thence our rivers; a not inconsiderable portion finding its way back to the land in some form; in addition to which, imported corn, meat, and other materials will contribute something to the restoration of our own cultivated land.

It is at the same time certain that so much of the refuse matters of our towns as becomes diluted with water in the degree recognized under the present sewerage system will be applicable as manure, on the large scale, only to succulent crops, and especially to grass-land; and, so far as this is the case, they will of course not *directly* contribute to the restoration, to the land under tillage, of the mineral constituents sent from it in its produce of corn and meat. When other descriptions of produce than corn and meat, such as roots, hay, or straw, are largely sold, compensation is generally made by the return to the land of stable- or town-manures of some kind. If this be not done, the loss of mineral constituents may indeed be very considerable.

In conclusion, whilst the authors insisted upon the importance of applying to agricultural purposes as much as possible of the valuable manuring matters of our towns, they at the same time believed that modern practices, taken as a whole, did not tend to exhaustion in anything like the degree that had been supposed by some.

* The accuracy of some of these analyses, however, is admitted as open to question: see Report by Magnus, Ann. d. Landwirthschaft, xiv. 2.



REPORT OF EXPERIMENTS

MADE AT RODMERSHAM, KENT,

ON THE

GROWTH OF WHEAT

BY

DIFFERENT DESCRIPTIONS OF MANURE,

FOR SEVERAL YEARS IN SUCCESSION ON
THE SAME LAND.

BY

J. B. LAWES, F.R.S., F.C.S., & Dr. J. H. GILBERT, F.R.S., F.C.S.

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EXPERIMENTS

ON THE

GROWTH OF WHEAT.

It is highly desirable, in a practical as well as scientific point of view, to determine, by means of careful experiments, whether or not the action of particular manures on particular crops is substantially similar in different descriptions of soil, and in different localities. With a view to provide information on this subject, a series of experiments was commenced in 1851 by Mr. Keary, on the Home Farm of the Earl of Leicester, at Holkham, in Norfolk; the results of which were published in the Society's Journal in 1855 (vol. xvi., part 1). The crop selected was wheat, and the arrangement of the manures was the same as on some of the most important plots in the experimental field here at Rothamsted (Herts), in which wheat has been grown every year since 1844. Sir John M. Tylden, who is the president of an agricultural club in the neighbourhood of Sittingbourne, in Kent, the members of which are accustomed to make visits of inspection of experimental or good practical farming, some years ago induced the club to pay such a visit to Rothamsted; after which they very liberally undertook to conduct, at their own expense, a series of experiments on the growth of wheat, the results of which would compare with those already obtained at Holkham, and with those of the experiments still in progress here at Rothamsted.

Accordingly, a field of 3½ acres, at Rodmersham, about 3½ miles from Sittingbourne, was set apart for the purpose, and divided into seven plots, of half an acre each, and the superintendence of the experiments was confided to Mr. George Eley, of Tong, who is the Secretary of the club.

The soil of the experimental field is described by Mr. Eley as "a mixed clay, upon a chalk subsoil, lying from 4 to 6 feet below the surface." The previous course of crops and management had been as follows:—In 1853, turnips, dressed with 2 cwts. guano

and 3 cwts. superphosphate of lime per acre, and the whole of the crop fed on the land; in 1854, barley; and a good dressing of London dung for beans in 1855; this being the usual preparation for wheat in that locality. The land was, therefore, to use Mr. Eley's words, "in a well-cultivated and fertile state." It was, in fact, as the results will show, in higher condition than was desirable when the object was to determine the character of the exhaustion, and therefore the character of the manures required for the crop, in that particular soil, under the ordinary system of cropping and management adopted. The action of the different manures was, however, sufficiently characteristic after the first crop of wheat had been taken.

The manures were always mixed at Rothamsted, from the same stocks as those employed for the Rothamsted experiments. The arrangement of the experiments, and the description and quantities of manure applied per acre, were as follows:—

Plot 1. Unmanured.

Plot 2. Mixed mineral manure, composed of—

300 lbs. sulphate of potass.
200 lbs. sulphate of soda.
100 lbs. sulphate of magnesia.
200 lbs. bone-ash
150 lbs. sulphuric acid* } Superphosphate of lime.

Plot 3. Ammonia-salts, comprising—

200 lbs. sulphate of ammonia.
200 lbs. muriate of ammonia.

Plot 4. "Ammonia-salts" (as plot 3), and "mixed mineral manure" (as plot 2).

Plot 5. 540 lbs. Peruvian guano.

Plot 6. 2000 lbs. rape cake.

Plot 7. 14 tons farmyard manure.

The above quantities were applied annually for the first three years of the experiments; the arrangement was also the same for the fourth year, with the exception that in experiments 2 and 4 the quantities of sulphate of potass were reduced from 300 lbs. to 200 lbs., and of sulphate of soda from 200 lbs. to 100 lbs. per acre. In the fifth and sixth seasons the crop was grown without any fresh application of manure.

By means of experiment 1, we ascertain the state of productiveness of the land without any manure, and so provide a standard by which to compare the effects of the different manures. By means of experiments 2, 3, 4, 6, and 7, it is ascertained whether a specially mineral, nitrogenous, or carbonaceous manure,

* Sp. gr. 1·7.

or some combination of them, is the most effective; and by means of the guano (experiment 5), which is the cheapest so-called artificial manure containing a large proportion both of nitrogen and phosphates, we are enabled to judge whether increase of crop can be obtained profitably by the use of such a combination.

The results obtained in each of the four years in which the manures were applied, in the two succeeding years without manure, and over the total period of six years, are given in a series of tables as follow (pp. 6-10):—

Table I. The dressed corn per acre, in bushels and pecks, and the total corn per acre, in lbs.

Table II. The straw (chaff, &c.) per acre, in lbs., and the total produce (corn and straw) per acre, in lbs.

Table III. The increase per acre, by manure, of dressed corn (bushels and pecks), and of total corn (lbs.).

Table IV. The increase, per acre, of straw (chaff, &c.), in lbs., and the increase of total produce (corn and straw), in lbs.

Table V. The weight, per bushel, of dressed corn, and the proportion of corn to 100 of straw in the produce, and in the increase by manure.

In the first year of the experiments the unmanured plot gave about 32½ bushels of dressed corn, and nearly 43 cwts. of straw per acre; the farmyard-manure gave only about 30⅔ bushels of dressed corn, but rather more than 56 cwts. of straw; and the greatest increase obtained by any of the manures was between 4 and 5 bushels of dressed corn, and between 15 and 16 cwts. of straw. It is obvious that, even unmanured, the condition of the land was almost as high as was compatible with the healthy growth and proper ripening of the crop—that it was, in fact, scarcely in a state to require manure at all, and therefore not in a condition to show very prominently the characteristic action of the different manures employed. The best preparation would have been to grow a crop of wheat over the whole field without manure, before commencing with the special manures. It is unfortunate, too, that the manures were only applied during four consecutive years; that during the two succeeding years, without manure, the seasons were very unfavourable, and the land had become somewhat foul; and that the experiments were entirely stopped before the influence of the manures had ceased, and their whole effect been ascertained.

Notwithstanding the unfavourable circumstances above mentioned, the results of the experiments at Rodmersham are very valuable; and, taking into consideration the very different condition of the land, they are entirely confirmatory of the conclusions that have been arrived at from experiments made

at

EXPERIMENTS made at RODMERSHAM, KENT, on the GROWTH of WHEAT by different descriptions of Manure, year after year on the same Land.

TABLE I.—PRODUCE per Acre, of DRESSED CORN in bushels, and of Total Corn in lbs.

Experiments.	Manures applied* for 1856-7-8-9. (Unmanured in 1860 and 1861.)	PRODUCE PER ACRE.											
		EACH YEAR.						TOTAL.			AVERAGE ANNUAL.		
		1856.	1857.	1858.	1859.	1860.	1861.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.
	Dressed Corn; Bushels and Pecks.												
1	Unmanured	32 1¼	25 1	24 3¼	19 3	7 1	15 2	102 0½	22 3	124 3½	25 2¼	11 1½	20 3¼
2	Mixed Mineral Manure	33 0½	29 3½	29 1¼	21 2¾	13 0½	17 3½	114 0	31 0	145 0	28 2	15 2	24 0¾
3	Ammonia Salts	36 3½	34 2½	31 0	23 1	15 3	19 1½	125 3	35 0½	160 3½	31 1¾	17 2¼	26 3¼
4	Mixed Mineral Manure and Ammonia Salts	33 2¼	41 0	32 1½	27 0	18 0	21 1¾	133 3¾	39 1¾	173 1½	33 2	19 2¾	28 3½
5	Guano	36 2	38 3	31 3½	25 0	17 1	21 0¼	132 0½	38 1¼	170 1½	33 0	19 0½	28 1½
6	Rape-cake	37 0¼	37 0½	33 0¼	27 0½	16 0	21 1	134 1½	37 1	171 2½	33 2½	18 2½	28 2½
7	Farmyard Manure ..	30 2½	33 0½	32 3½	25 2	14 1	19 3¼	122 0½	34 0¼	156 0¾	30 2¼	17 0	26 0¼
	Total Corn; lbs.												
1	Unmanured	1959	1602	1501	1199	462	1032	6261	1494	7755	1565	747	1292
2	Mixed Mineral Manure	1975	1934	1815	1314	807	1171	7038	1978	9016	1760	989	1503
3	Ammonia Salts	2204	2190	1883	1392	917	1245	7669	2162	9831	1917	1081	1638
4	Mixed Mineral Manure and Ammonia Salts	1950	2570	1941	1620	1096	1395	8081	2491	10572	2020	1246	1762
5	Guano	2112	2446	1927	1508	1006	1371	7993	2377	10370	1998	1189	1728
6	Rape-cake	2233	2316	2008	1621	932	1412	8178	2344	10522	2045	1172	1754
7	Farmyard Manure ..	1822	2114	2026	1537	864	1288	7499	2152	9651	1875	1076	1608

* For full particulars of the Manures see p. 4.

TABLE II.—STRAW, and TOTAL PRODUCE (Corn and Straw), per Acre; lbs.

Experiments.	Manures applied* for 1856-7-8-9. (Unmanured in 1860 and 1861.)	PRODUCE PER ACRE.											
		EACH YEAR.						TOTAL.			AVERAGE ANNUAL.		
		1856.	1857.	1858.	1859.	1860.	1861.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.
	Straw (Chaff, &c.); lbs.												
1	Unmanured	4798	2486	2691	3395	1624	1833	13,370	3457	16,827	3343	1728	2805
2	Mixed Mineral Manure	6274	3154	3093	3277	2338	2309	15,798	4647	20,445	3949	2323	3408
3	Ammonia Salts	6528	4350	3825	4451	2686	2795	19,154	5481	24,635	4788	2741	4106
4	Mixed Mineral Manure and Ammonia Salts	6490	5310	5098	5887	3028	2889	22,785	5917	28,702	5696	2958	4783
5	Guano	6348	4834	4712	5408	3011	2780	21,302	5791	27,093	5326	2896	4516
6	Rape-cake	6430	4458	3809	4988	2715	2854	19,685	5569	25,254	4921	2784	4209
7	Farmyard Manure ..	6302	3234	3835	4264	2629	2984	17,635	5613	23,248	4409	2807	3875
	Total Produce (Corn and Straw); lbs.												
1	Unmanured	6757	4088	4192	4594	2085	2865	19,631	4950	24,581	4908	2475	4097
2	Mixed Mineral Manure	8249	5088	4908	4591	3145	3480	22,836	6625	29,461	5709	3313	4910
3	Ammonia Salts	8732	6540	5708	5842	3603	4040	26,822	7643	34,465	6706	3822	5744
4	Mixed Mineral Manure and Ammonia Salts	8440	7880	7038	7507	4123	4284	30,865	8407	39,272	7716	4204	6545
5	Guano	8460	7280	6639	6916	4017	4151	29,295	8168	37,463	7324	4084	6244
6	Rape-cake	8663	6774	5816	6610	3646	4266	27,863	7912	35,775	6966	3956	5963
7	Farmyard Manure ..	8124	5348	5861	5801	3493	4272	25,134	7765	32,899	6284	3883	5483

* For full particulars of the Manures see p. 4.

TABLE III.—INCREASE per Acre by MANURE; Dressed Corn, bushels, and Total Corn, lbs.

Experiments.	Manures applied* for 1856-7-8-9. (Unmanured in 1860 and 1861.)	INCREASE PER ACRE.											
		EACH YEAR.						TOTAL.			AVERAGE ANNUAL.		
		1856.	1857.	1858.	1859.	1860.	1861.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.
	Dressed Corn; Bushels and Pecks.												
2	Mixed Mineral Manure	0 3½	4 2½	4 2	1 3¾	5 3½	2 1½	11 3½	8 1	20 0½	2 3¾	4 0½	3 1½
3	Ammonia Salts	4 2¼	9 1½	6 0¾	3 2	8 2	3 3½	23 2½	12 1½	36 0	5 3½	6 0¾	6 0
4	Mixed Mineral Manure and Ammonia Salts	1 1	15 3	7 2½	7 1	10 3	5 3¾	31 3½	16 2¾	48 2	7 3¾	8 1¼	8 0¼
5	Guano	4 0¾	13 2	7 0	5 1	10 0	5 2¼	29 3¾	15 2¼	45 2	7 1¾	7 3	7 2¼
6	Rape-cake	4 3	11 3½	8 1	7 1½	8 3	5 3	32 0¾	14 2	46 2¾	8 0	7 1	7 3¼
7	Farmyard Manure ..	−1 2¾	7 3½	8 0¼	5 3	7 0	4 1¼	20 0	11 1¼	31 1¼	5 0	5 2½	5 1
	Total Corn; lbs.												
2	Mixed Mineral Manure	16	332	314	115	345	139	777	484	1261	195	242	211
3	Ammonia Salts	245	588	382	193	455	213	1408	668	2076	352	334	346
4	Mixed Mineral Manure and Ammonia Salts	−9	968	440	421	634	363	1820	997	2817	455	499	470
5	Guano	153	684	426	309	544	339	1732	883	2615	433	442	436
6	Rape-cake	274	714	507	422	470	380	1917	850	2767	480	425	462
7	Farmyard Manure ..	−137	512	525	338	402	256	1238	658	1896	310	329	316

* For full particulars of the Manures see p. 4.

TABLE IV.—INCREASE per Acre by MANURE; STRAW, and TOTAL PRODUCE (Corn and Straw); lbs.

Experiments.	Manures applied* for 1856-7-8-9. (Unmanured in 1860 and 1861.)	INCREASE PER ACRE.											
		EACH YEAR.						TOTAL.			AVERAGE ANNUAL.		
		1856.	1857.	1858.	1859.	1860.	1861.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.	4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.
	Straw (Chaff, &c.); lbs.												
2	Mixed Mineral Manure	1476	668	402	−118	715	476	2,428	1190	3,618	606	595	603
3	Ammonia Salts	1730	1864	1134	1056	1063	962	5,784	2024	7,808	1445	1013	1301
4	Mixed Mineral Manure and Ammonia Salts	1692	2824	2407	2492	1404	1056	9,415	2460	11,875	2353	1230	1978
5	Guano	1550	2348	2021	2013	1388	947	7,932	2334	10,266	1983	1168	1711
6	Rape-cake	1632	1972	1118	1593	1091	1021	6,315	2112	8,427	1578	1056	1404
7	Farmyard Manure ..	1504	748	1144	869	1005	1151	4,265	2156	6,421	1066	1079	1070
	Total Produce (Corn and Straw); lbs.												
2	Mixed Mineral Manure	1492	1000	716	−3	1060	615	3,205	1675	4,880	801	838	813
3	Ammonia Salts	1975	2452	1516	1248	1518	1175	7,191	2693	9,884	1798	1347	1647
4	Mixed Mineral Manure and Ammonia Salts	1683	3792	2846	2913	2038	1419	11,234	3457	14,691	2808	1729	2448
5	Guano	1703	3192	2447	2322	1932	1286	9,664	3218	12,882	2416	1609	2147
6	Rape-cake	1906	2686	1624	2016	1561	1401	8,232	2962	11,194	2058	1481	1866
7	Farmyard Manure ..	1367	1260	1669	1207	1408	1407	5,503	2815	8,318	1376	1408	1386

* For full particulars of the Manures see p. 4.

TABLE V.—WEIGHT per Bushel of DRESSED CORN; and Proportion of Corn to Straw.

Experiments	Manures applied* for 1856-7-8-9. (Unmanured in 1860 and 1861.)	EACH YEAR. 1856.	1857.	1858.	1859.	1860.	1861.	AVERAGE. 4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.	IN THE INCREASE OF PRODUCE. 4 Years, 1856-9.	2 Years, 1860-1.	6 Years, 1856-61.
	Weight of Dressed Corn per Bushels, lbs. and tenths.												
1	Unmanured	59·5	61·5	59·0	57·5	54·0	61·3	59·4	57·7	58·8			
2	Mixed Mineral Manure	58·8	63·0	60·5	58·0	54·3	60·5	60·1	57·4	59·2			
3	Ammonia Salts	58·3	61·5	58·8	55·3	53·5	57·8	58·5	55·7	57·5			
4	Mixed Mineral Manure and Ammonia Salts	56·9	60·3	58·0	56·0	56·3	60·8	57·8	58·6	58·1			
5	Guano	56·9	61·0	58·3	55·0	53·8	58·8	57·8	56·3	57·3			
6	Rape-cake	59·4	60·3	59·5	56·5	54·0	61·0	58·9	57·5	58·5			
7	Farmyard Manure ..	58·3	62·3	60·5	57·8	54·0	60·5	59·7	57·3	58·9			
	Proportion of Corn to 100 of Straw.												
1	Unmanured	40·8	64·4	55·8	35·2	28·3	56·3	46·8	43·2	46·1			
2	Mixed Mineral Manure	31·5	61·3	58·7	40·1	34·5	50·7	44·5	42·6	44·1	32·0	40·7	34·9
3	Ammonia Salts	33·8	50·3	49·2	31·3	34·1	44·6	40·0	39·4	39·9	24·3	33·0	26·6
4	Mixed Mineral Manure and Ammonia Salts	30·1	48·4	38·1	27·5	36·2	48·3	35·5	42·1	36·8	19·3	40·5	23·7
5	Guano	33·3	50·6	40·9	27·9	33·4	49·3	37·5	41·1	38·3	21·8	37·8	25·5
6	Rape-cake	34·7	52·0	52·7	32·5	34·3	49·5	41·5	42·1	41·7	30·4	40·2	32·8
7	Farmyard Manure ..	28·9	65·4	52·8	36·1	32·9	43·2	42·5	38·3	41·5	29·0	30·5	29·5

* For full particulars of the Manures see p. 4.

at Rothamsted, and elsewhere, regarding the character of the manures required for the increased growth of wheat on land under the ordinary conditions of cropping and cultivation in our rotations. They are, moreover, perfectly consistent with the experience of common practice on the point.

It is worthy of remark that after the land had been well dunged, and grown a crop of beans, the greatest increase, especially of corn, obtained in the first year was where the manure was the most nitrogenous. Thus, the ammonia-salts alone, the guano, and the rape-cake, each gave 4 to 5 bushels' increase of dressed corn; whilst the mineral manure, and the mineral manure and ammonia-salts together, gave only about 1 bushel. The ammonia-salts alone also gave rather more increase of straw than any of the other manures—more even than the mixed mineral manure and ammonia-salts together. The produce of the unmanured plot in the second and succeeding years showed, however, that the condition of the land had then become reduced; and it is, therefore, from the average results of each of the different manures taken over a series of years, that we shall be able best to judge of the character of the exhaustion induced by the growth of the wheat crop in that particular soil.

It is proposed to make a few comments: first, on the produce during the four years of the application of the manures; secondly, on that of the two years after the cessation of the manuring, showing the influence of the residue of the manures previously applied; and then on the total amount of increase obtained in the six years by the different manures.

Plot 1. *Unmanured.*—As already observed, the produce without manure was, in the first year, about 32¼ bushels of dressed corn and nearly 43 cwts. of straw. In the five succeeding years it was, respectively, 25¼, 24¾, 19¾, 7¼, and 15½ bushels of dressed corn, and about 22¼, 24, 30¼, 14½, and 16½ cwts. of straw. But, a part only of this great reduction in the produce was due to the reduction of the condition of the land as affected by previous manuring; for, as already said, in the last two years of the experiments the seasons were unfavourable and the land had become somewhat foul. Excluding the first year, the average produce of the next three years was 23¼ bushels of dressed corn, and 25½ cwts. of straw; and the average of the five years, without manure, that is, excluding the first year and including the last two unfavourable seasons, was 18½ bushels of dressed corn and 21½ cwts. of straw. Here at Rothamsted (Herts) where wheat had been grown without manure for a dozen previous consecutive years, the average produce of the same five seasons was 16 bushels of dressed corn and 14½ cwts. of straw, or 2½ bushels of dressed corn and 7 cwts. of straw less than at Rodmersham

(Kent). But as a standard by which to compare the effects of the different manures during the four years of their application in the Kent experiments, it will be necessary to take the average of the first four years without manure, which was 25½ bushels of dressed corn and about 30 cwts. of straw; against which there were at Rothamsted (Herts), over the same seasons, only 17¼ bushels of dressed corn and about 15½ cwts. of straw, or not much more than two-thirds as much corn and half as much straw as at Rodmersham.

Plot 2. *Mixed Mineral Manure.*—This manure supplied potass, soda, lime, magnesia, phosphoric acid, and sulphuric acid; in fact, an abundance of nearly all the mineral constituents required by the crop, excepting silica. The average annual increase it yielded, over the four years of its application, was about 3 bushels of dressed corn and 5½ cwts. of straw. This was almost precisely the same amount of increase of corn as was yielded by the same manures over the same seasons here at Rothamsted, but nearly 4 cwts. more straw.

Plot 3. *Ammonia-Salts alone.*—The quantity employed contained much more nitrogen than could be taken up by the increase of produce, and quite as much as can be employed for the average of soils and seasons without getting an over-luxuriant and laid crop. The average annual increase yielded over the four years of the application was about 6 bushels of dressed corn and nearly 13 cwts. of straw. This, again, was almost exactly the same increase of corn, but nearly twice as much increase of straw, as was obtained by the same manure, in the same seasons at Rothamsted, after their application there for a dozen years consecutively.

Both at Rodmersham and at Rothamsted, then, ammonia-salts alone increased the wheat-crop, for a series of successive years, considerably more than did mineral manure alone.

Plot 4. *Mixed Mineral Manure and Ammonia-Salts.*—This manure supplied the same mineral constituents as in experiment 2, and the same amount of ammonia, or nitrogen, as in experiment 3; but it contained no carbon, of which about 40 per cent. of the dry substance of the crop consists. The average annual increase it yielded over the four years was about 8 bushels of dressed corn and 21 cwts. of straw; or about 5 bushels more corn and 15½ cwts. more straw than by the mineral manure alone, and about 2 bushels more corn and 8 cwts. more straw than by the ammonia-salts alone.

It has been seen that both mineral manures alone, and ammonia-salts alone, yielded almost identically the same amounts of increase of corn over the first four years of the experiments at Rodmersham (Kent) as they did over the same years at Rothamsted (Herts), where wheat had been grown for a dozen previous con-

secutive years. The increase of straw by each of these manures, used separately, was, however, greater in the Kent experiments than at Rothamsted. The effect was altogether different when the mineral and nitrogenous manures were used together;—the combination yielding an average annual increase of about 21 bushels of corn and 22½ cwts. of straw at Rothamsted, against only 8 bushels of corn and 21 cwts. of straw at Rodmersham. Not only was the annual increase of both corn and straw the greater at Rothamsted, but the actual produce per acre, per annum, of dressed corn, was greater by about 5½ bushels; though that of the straw was about 13 cwts. less.

In both localities, then, the mixed mineral and ammoniacal manure greatly increased the crop, and the increase was greater when the two were used together than when each was used separately. But at Rodmersham, where the land was in comparatively high condition, the heavy manuring tended to over-luxuriance, and excessive proportion of straw; whereas, at Rothamsted, with an average of about half a ton less total produce per acre per annum, there was a considerably greater actual amount of corn, and of course a greater proportion of corn to straw, and also a greater increase of both corn and straw.

Plot 5. *Guano.*—The guano employed supplied a large quantity of phosphate of lime, small quantities of alkaline salts, and rather more than four-fifths as much ammonia or nitrogen as the quantity of ammonia-salts of experiments 3 and 4. It yielded an average annual increase of about 1½ bushel of dressed corn, and 4¾ cwts. of straw more than the ammonia-salts alone; and only about ½ bushel of dressed corn and 3¼ cwts. of straw less than the mixed mineral manure and ammonia-salts together. It will presently be seen that the guano gave far more increase, in proportion to its cost, than any of the other manures.

Plot 6. *Rape-cake.*—The amount of rape-cake employed would contain rather more nitrogen than the ammonia-salts of experiments 3 and 4, but in a condition in which it would be more slowly rendered available for the plant; it would contain a considerable quantity of mineral constituents; also a large amount of carbonaceous matter, yielding carbonic acid in the soil. It gave only the same average annual increase of corn (about 8 bushels), and 6¾ cwts. less straw than the mixed mineral manure and ammonia-salts (plot 4), which contained a less total amount of nitrogen, and no carbonaceous matter whatever. This is perfectly consistent with results obtained at Rothamsted, which show the non-utility of supplying carbonaceous manure for wheat and other grain-crops.

Plot 7. *Farmyard Manure.*—The quantity employed would contain more of every constituent, mineral and organic, than the

crop to be grown; and it would supply a large amount of available silica, and a large amount of carbonaceous matter beyond that of any of the other manures. Notwithstanding this, it gave, over the four years of its application, an average annual produce of about 3 bushels less dressed corn and about 11½ cwts. less straw than the mixed mineral manure and ammonia-salts; and about 2½ bushels less corn and about 8¼ cwts. less straw than the guano—neither of which would supply either silica or carbonaceous matter. This result is also perfectly consistent with that obtained at Rothamsted and elsewhere. It is not to be concluded from this, however, that the farmer may with impunity grow large white-straw crops by means of artificial manures without a due supply of farmyard manure to the land at some period of the rotation.

Thus, the results obtained during the four years that the manures were applied, showed that mineral manures increased the wheat-crop but little, ammonia-salts much more, mineral manures and ammonia-salts used together more than either, or both, used separately; that Peruvian guano, containing both mineral and nitrogenous constituents, gave a considerable amount of increase; but that carbonaceous manures had no perceptible effect. They further showed that the condition of the land was higher than was desirable for the purposes of the experiments, the result of which was, not only that the seasons set a limit to the amount of crop, and therefore to that of the increase produced, below that which the manures might otherwise have yielded, but that the increase consisted of a very undue proportion of straw.

The first season after the cessation of the manuring (1859-60) was a very unfavourable one, and the produce on the permanently unmanured plot was only 7¼ bushels of dressed corn, and about 14½ cwts. of straw. The next season (1860-61) was not very much better, and yielded, on the same plot, only 15½ bushels of dressed corn, and about 16½ cwts. of straw. But the whole of this decline of crop is not to be attributed either to gradual reduction of the condition of the land, or to the badness of the seasons; for, as already noticed, the land, which had for the first few years been very clean, had, by this time, become somewhat foul by the continuous cropping.

Although the produce of the continuously unmanured plot, which supplied the standard by which to compare that of the others, was so much less during these two concluding years of the experiments, the average increase of dressed corn on the other plots, due to the residue of the manures previously applied, was, in every case excepting that of the rape-cake, even somewhat greater than during the seasons of the application. The increase

of straw was, however, in every case excepting that of the farm-yard manure, less than formerly, and generally very much less.

Thus, the amounts of increase obtained for two years after the application of the manures had been stopped, further show that the condition of the land was too high for the full action of the manures in the years of their application. They also show that their influence was not even then exhausted; and further evidence of this is to be found in the fact, that calculation leads to the conclusion that, in these Rodmersham experiments, there was a less proportion of the nitrogen supplied in the manures in the four years, recovered in the increase of the six years, and in some cases much less, than is sometimes recovered in the crop immediately succeeding the application of a nitrogenous manure. Under favourable circumstances, from 40 to 50 per cent. of the nitrogen supplied in an artificial manure for wheat may be recovered in the increase of a first crop. But it is estimated that, in the cases of the rape-cake and of the ammonia-salts alone, there was only about one-fourth, and in those of the mineral manure and ammonia-salts, and of the guano, under 40 per cent. of the nitrogen supplied in the manure of the four years recovered in the increase of the six years.

It will still be useful to give an estimate of the value of the increase so far obtained, by the side of the cost of the manures applied in one or two of the experiments.

The mixed mineral manures of plot 2 were far too expensive in proportion to the amount of increase they yielded, for it to be at all worth while to reckon the cost against the increase in their case. Looking to the objects in view, it was still quite essential to have the evidence of direct experiment as to their effect.

Ammonia-salts are, generally, neither so cheap a source of nitrogen, nor are they, when used alone, so good a manure for corn-crops as Peruvian guano, which contains a large proportion of phosphates as well as nitrogen. Rape-cake, though a recognised manure in the market for wheat, acts somewhat more slowly for the amount of nitrogen it contains than guano. It will be well, for the sake of comparison, to show the cost of the manure, and the value of the increase of the three manures—rape-cake, ammonia-salts, and Peruvian guano. This is done in the following table (p. 16).

Reckoning the value of the increase against the cost of the manures, there is a considerable margin in favour both of the ammonia-salts and the guano, but particularly of the guano. The evidence further goes to show that these active nitrogenous manures are by no means fully exhausted in the first year of their application. The quantity of guano used—nearly 5 cwts. to the acre—was, however, much more than is usually applied; indeed

TABLE VI.

Manures applied per acre in 4 Years.			Increase obtained per acre in 6 Years.				Cost of Manure.	Value of Increase.	Difference.
			Corn.		Straw.				
Description.	Quantities.	Price per Ton.	Bushels.	Price per Bushel.	Cwts.	Price per Cwt.			
	lbs.	£. s.		s. d.		s. d.	£. s. d.	£. s. d.	£. s. d.
Rape-cake . . .	8000	5 10	46¾	7 0	75½	1 3	19 12 10	21 1 4	1 8 6
Sulphate of Ammonia	800	15 0	} 36	7 0	69¾	1 3	12 10 0	16 19 2	4 9 2
Muriate of Ammonia	800	20 0	}						
Peruvian Guano . .	2160	12 10	45½	7 0	91⅔	1 3	12 1 1	21 13 2	9 12 1

indeed, much more than it is desirable to apply in ordinary practice. Nor should it be inferred from the plan and results of these experiments, that the practice of growing a series of corn-crops by means of artificial manures is to be recommended. But when these results are considered by the side of those obtained at Rothamsted, Holkham, and elsewhere, and with the light of the common experience of almost every arable district of the country, the practical conclusion undoubtedly is, that highly nitrogenous manures much increase the produce of grain-crops under the circumstances in which these are generally grown in our rotations.

Peruvian guano, which contains a large quantity of phosphates, as well as nitrogen-yielding matter, is one of the best artificial manures for wheat; and 2 to 3 cwts. per acre, sown broadcast before the seed, and harrowed into the land, will generally be sufficient. When ammonia-salts are used, about 2 cwts. per acre may be employed, and 1 to 2 cwts. of superphosphate of lime should at the same time be applied. The above quantities are such as should generally be employed when the grain-crop is grown in the ordinary course of rotation, and the land is considered to be not highly enough manured to carry as heavy a crop as the average of seasons will well ripen.

But another great advantage to the farmer of the nitrogenous and phosphatic manures now in such general use is that, provided the land be well dunged once in the course of the rotation, he may, without injury to it, by their means frequently take an extra grain-crop in the course;—for example, barley or oats after wheat, as the description and condition of the soil and the locality may indicate. In such cases, 1½ time or twice as much of the artificial manure should be used as when the crop is grown in the ordinary rotation.

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THE

EFFECT OF DIFFERENT MANURES

ON THE

MIXED HERBAGE OF GRASS-LAND.

BY

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EFFECTS OF DIFFERENT MANURES

ON THE

MIXED HERBAGE OF GRASS-LAND.

In Vol. XIX., Part II., and Vol. XX., Parts I. and II. of the Journal of the Royal Agricultural Society, we gave a Report on Experiments with different manures on permanent meadow land, in which we treated of the subject under the following heads:—

Part I. The produce of hay, per acre.
Part II. The produce of constituents, per acre.
Part III. The description of plants developed by different manures.
Part IV. The chemical composition of the hay.

Perhaps the most striking points brought out in the inquiry, were those which illustrated the very great difference in the description and character of the plants developed by the different manures. The general results arrived at under this head, may be very briefly re-stated here.

The unmanured crops, and the light ones grown by manure, were by far the most complex in character; consisting of a comparatively large number of species of plants, or descriptions of herbage, and showing less predominance of a few species than did the more bulky produce obtained by means of more active manures. The smaller crops consisted not only of a greater variety of Graminaceous herbage, or grasses properly so called, but also contained a greater variety, and greater proportion, of miscellaneous or weedy herbage.

As a rule, whatever the description of manure employed, any considerable increase of crop was accompanied by greater simplicity of herbage, greater predominance of grasses proper, and also, generally, a greater predominance of individual species, as well among the Graminaceous or grassy, the Leguminous, and the miscellaneous herbage.

But different descriptions of manure had very different effects.

Mineral manures alone (salts of potass, soda, magnesia, and superphosphate of lime) only moderately increased the amount of crop; rather diminished the proportion of the grasses, and

considerably that of the weedy herbage; greatly increased the amount per acre, and the proportion in the produce, of the Leguminous herbage, especially the perennial red clover and the meadow vetchling; and also enhanced the ripening tendency, rather than luxuriance of foliage.

Ammonia-salts alone, considerably increased the amount per acre, and the proportion in the crop, of the grasses, but tended very remarkably to the development of leaf rather than of stem and seed; and they also diminished the proportion of both the Leguminous and the weedy herbage, the former being almost excluded.

Mixtures of both the mineral manure and ammonia-salts, gave by far the greatest increase of crop. The produce so obtained was in a much larger proportion Graminaceous, or grassy, than that yielded under any other conditions; clover and other Leguminous plants were almost entirely excluded; and the number of species and amount of weedy herbage were but small, though some few plants grew luxuriantly. Lastly, comparatively few species of grasses contributed to the great bulk of this very luxuriant and highly Graminaceous produce, and the development of stem and seed was very remarkable.

Farm-yard manure alone, with the increase of total produce, also increased the amount and proportion of the Graminaceous herbage; and diminished the variety, and the proportion, of the Leguminous and the miscellaneous herbage.

Farm-yard manure and ammonia-salts gave considerably more increase of crop than farm-yard manure alone; and the produce contained a large proportion of Graminaceous and miscellaneous, but very little Leguminous herbage.

This great variety in the herbage, both as to the description of the plants developed, and the character of their growth, according to the manures employed, and to the consequent amount of crop obtained, is obviously a point of great practical interest and importance in its bearing upon the question of the proper manures to be employed to increase the produce of grass-land.

The results briefly enumerated above are also of great interest in another point of view.

Thus, exclusively mineral manures, when applied to Graminaceous plants grown separately (as wheat, barley, or oats, under ordinary circumstances), produce very similar effects to those upon the allied plants of the mixed herbage; that is to say, they increase the crop comparatively little, but prominently develop the seeding tendency; and again, when these manures are applied to Leguminous crops grown separately, as in the case of the allied plants of the mixed herbage, they considerably increase the luxuriance of their growth.

Ammonia-salts, on the other hand, which produce such characteristic effects upon the growth of the Graminaceous plants of the mixed herbage, have also a marked influence upon that of the Graminaceous plants grown separately in rotation, and but little on that of the Leguminous ones so grown.

For various reasons, therefore, both practical and scientific, it seemed very desirable that the subject should be further investigated, both here and elsewhere. The experiments at Rothamsted have, accordingly, been continued up to the present time, and they are still in progress.

Our first report, to which we have been referring, gave the results of the first three seasons (1856, 1857, and 1858), relating to three divisions of the subject, namely—the produce of hay per acre, the produce of constituents per acre, and the chemical composition of the hay—and on these points we have now on hand the accumulated results of four more seasons. The results formerly given on the remaining branch of the subject—*the description of plants developed by the different manures*—related to the produce of the third season only, 1858; and the further details obtained on this head have reference to the produce of the seventh season, 1862. It is to these that it is proposed to confine attention on the present occasion, presenting only such an outline of the voluminous records as will bring to view the points of most interest to the readers of an Agricultural Journal.

Method of Experimenting.

Taking advantage of the experience gained in some attempts to separate and determine the proportion of the different plants, in carefully averaged and weighed samples of the produce in the previous year (1857), the produce of 1858 had been separated into—(1) Graminaceous herbage, stems bearing flower or seed; (2) Graminaceous herbage, detached leaves and indeterminate stems; (3) Leguminous herbage; (4) Miscellaneous herbage, chiefly weeds. The components classified under these heads gave from 14 to 23 different descriptions of herbage; and, no doubt, the results, so far as they went, clearly and truthfully indicated the characteristic and comparative distribution of plants on the different plots. But as there remained, in the separations in question, an amount equal in several cases to a fourth, and in one to more than a half of the whole produce, to be set down as Graminaceous herbage in "detached leaves and indeterminate stems," to the components of which the specific names could not with any confidence be given, it seemed desirable, in again taking up the subject, to follow it out in considerably more of detail. Accordingly, in the separations recently made, of the produce of 1862,

it was sought to determine the species to which the detached leaves and imperfect stems belonged, and so to include in the amount given for each grass, as far as possible its total yield, whether in culm bearing flower and seed, or in a less definite condition. The classification of the Graminaceous herbage will, therefore, on the present occasion, be somewhat different; and hence the present and the former results will not be strictly comparable.

It will be obvious that to conduct the work on the plan just indicated, not only involved an immense amount of labour, but required very considerable technical knowledge and experience in those superintending the separations. Accordingly, we applied to several botanical friends for a competent botanical assistant; and we have now to express our best thanks to Dr. J. D. Hooker, of Kew, for recommending to us Mr. W. Sutherland, a young man who, as foreman of the "Hardy Herbaceous ground" in the Kew Gardens, had had, to use Dr. Hooker's words, "the charge of a most extensive named collection of herbaceous plants (some 4-5000), including a good collection of grasses." We have also much satisfaction in bearing testimony to the competency of Mr. Sutherland for the work he undertook, and to the conscientious and assiduous manner in which he has performed his tedious and difficult task.

The mode of taking the samples for the botanical separations was as follows: eight or ten mowers were put upon the half-acre experimental plot, and small quantities of grass were taken immediately after the scythe from each swathe, until nearly the whole of the plot was down. The quantities so taken, amounting to very many times more than the required sample, were then carefully mixed on a cloth, so as to shake out as little seed as possible, and from the bulk a sample of 10 lbs. was immediately weighed, before any material change in the condition of the grass could take place by evaporation.

The samples taken as above described were spread out to dry at the ordinary temperature, and afterwards carefully preserved for future operation.

In all, twenty samples have been submitted to botanical analysis; occupying Mr. Sutherland for about four months, and another assistant, and from three to half a dozen boys, for a period of nearly six months.

The plan adopted in the first instance was to work down each sample to the point of something like equal difficulty of further separation. The remaining undetermined residue was then put into a sieve, and the larger stemmy and leafy portions were thus separated from the shedded flowers and seeds, and finely broken leafy matter. The mass of the latter was then separated, by

means of other sieves of varying fineness, into four or five different lots, in order to facilitate the examination and identification of its components; and notes were made accordingly as to their apparent character. But it was found that there still remained, in some cases, nearly one-fourth of the original sample as undetermined stemmy and leafy residue. Hence, all such residues that amounted to more than 10 per cent. of the original sample were afterwards submitted to a further separation—a most tedious labour—which, however, has in very few cases left as much as 10 per cent. of undetermined matter. Still, after these further separations, the relative proportions of the final stemmy and leafy residues will, to some extent indicate the ease or difculty attending the separations and identifications, and at the same time, be some indication of the character of development of the herbage. For, it will be readily understood that a very luxuriant and stemmy Graminaceous produce, would be much more easily separated into its components, than a mass consisting almost exclusively of leafy herbage. Indeed, whilst some of the individual samples required more than a week for the first, and afterwards some days for the second separation, others were worked much more easily.

The numerical results of the inquiry, showing the proportion per cent. in each sample, of each separated portion, are given in the large folding Table, facing p. 36; in which the individual plants, or descriptions of herbage otherwise defined, are classified into—

1.—Graminaceous herbage:
   Determined species;
   Undetermined stem and leaf;
   Shedded flowers and seeds, &c. (chiefly Graminaceous).
2.—Leguminous herbage.
3.—Miscellaneous herbage.

And, as will be seen, the different plants composing the Miscellaneous or weedy herbage, are classified into the Natural Orders to which they respectively belong.

The following is a detailed statement of the manuring of the different plots; a brief description of which is given under the corresponding plot-numbers in the Tables. Unless otherwise stated, the same description and amount of manure has been applied to the respective plots every year since the beginning of the experiments in 1856. The quantities are given *per acre.*

Plot 1.—Unmanured.
Plot 2.—Unmanured (duplicate plot at the further end of the series).

Plot 3 *a*.—Superphosphate of lime; composed of 200 lbs. bone-ash, and 150 lbs. sulphuric acid of sp. gr. 1·7. 4th season, commencing in 1859; sawdust alone the three previous seasons.

Plot 3 *b*.—Superphosphate of lime; and 400 lbs. ammonia-salts (equal parts sulphate and muriate of commerce, supplying about 82 lbs. nitrogen per acre). 4th season, commencing in 1859; the three previous seasons sawdust alone.

Plot 4.—400 lbs. ammonia-salts.

Plot 5.—400 lbs. ammonia-salts; and 2000 lbs. sawdust.

Plot 6.—275 lbs. nitrate of soda of commerce (containing about 41 lbs. nitrogen). 5th season, commencing 1858.

Plot 7.—550 lbs. nitrate of soda (containing about 82 lbs. nitrogen). 5th season, commencing in 1858.

Plot 8.—Mixed mineral manure, composed of—

300 lbs. sulphate of potass.
200 lbs. sulphate of soda.
100 lbs. sulphate of magnesia.
Superphosphate of lime, as above.

Plot 9.—Mixed mineral manure; and 2000 lbs. sawdust. (The mixed mineral manure as Plot 8 to 1861 inclusive, and in 1862 the sulphate of potass excluded, and the amount of sulphate of soda raised to 500 lbs.)

Plot 10.—Mixed mineral manure, as Plot 8; and 400 lbs. ammonia-salts.

Plot 11.—Mixed mineral manure, as Plot 9; and 400 lbs. ammonia-salts.

Plot 12 *a*.—Mixed mineral manure, as Plot 8; 400 lbs. ammonia-salts; and 2000 lbs. cut wheat-straw.

Plot 12 *b*.—Duplicate of Plot 12 *a*, but rather sheltered on the west by trees.

Plot 13 *a*.—Mixed mineral manure, as Plot 8; and 800 lbs. ammonia-salts, equal about 164 lbs. nitrogen (only 400 lbs. ammonia-salts in 1859, 1860, and 1861).

Plot 13 *b*.—Mixed mineral manure, as Plot 13 *a*, to 1861 inclusive; the same with 200 lbs. silicate of soda and 200 lbs. silicate of lime in addition in 1862; and 800 lbs. ammonia-salts (only 400 lbs. ammonia-salts in 1859, 1860, and 1861).

Plot 14.—Mixed mineral manure, as Plot 8; and 275 lbs. nitrate of soda. 5th season, commencing in 1858.

Plot 15.—Mixed mineral manure, as Plot 8; and 550 lbs. nitrate of soda. 5th season, commencing in 1858.

Plot 16.—14 tons farm-yard manure.
Plot 17.—14 tons farm-yard manure; and 200 lbs. ammonia-salts.

With the view of both controlling and adding to the numerical results of the botanical separations, it was decided to have systematic series of notes taken on the ground. To this end, between three and four weeks prior to the date of cutting were devoted to making observations, as under:—

1. On each plot seriatim; remarking the predominance, and character of development, of the different plants.
2. On each of the most important plants seriatim; comparing its predominance, and character of development, on the different plots.
3. On the relative conditions of ripeness of the plots generally, and of individual descriptions of plants, just before cutting.

Then, after the crop was cut, and before its removal from the ground, further notes were taken, with the full view of the produce of the entire plot then at command, the former ones having been made only at either end of the respective plots.

Lastly, notes on the second crop were taken.

In the separations of 1858, the number of species determined in any one sample in no case amounted to twenty; the undetermined Graminaceous herbage was, however, subdivided into four or five different lots, supplying, in addition to the defined species, so many different descriptions of herbage; but in the separations of 1862, forty or more defined species were in some cases identified. It is not supposed that a greater number of plants occurred in the produce of 1862 than in that of 1858. The result is doubtless due to the much greater amount of attention and labour bestowed upon the more recent separations. There is, however, no doubt, that, although the more general characteristics of the herbage on the respective differently-manured plots remain the same as formerly—that is to say, as to the general predominance respectively of Graminaceous, Leguminous, and Miscellaneous herbage, and tendency to stemmy or leafy development—yet that there is a considerably altered predominance of particular plants, as a further consideration of the results will show.

It is not proposed to comment in detail upon the numerical results given in the large folding Table (facing p. 36), nor to quote at any length from the voluminous written observations to which reference has been made, as such a treatment of the subject is more suitable to the pages of a Botanical than of an Agricultural Journal.

The most important practical points for consideration are those which illustrate the character of the herbage *in relation to the manures employed, and to the amounts of crop yielded.* In relation to these points, therefore, we shall briefly consider—

1. The general description, and proportion per cent., of the different kinds of herbage (Graminaceous, Leguminous, or Miscellaneous), and the number of species.
2. The description, and proportion per cent., of the predominating species.
3. The tendency to the development of leafy or stemmy produce, and the order of ripeness.

I.—*The general description, and proportion per cent., of the different kinds of herbage (Graminaceous, Leguminous, and Miscellaneous), and the number of species, in relation to the manures employed, and to the amounts of crop yielded.*

In Table II. (pp. 12-13), are given the results relating to this branch of the subject. On the left hand will be found a short description of the manures employed, and a column showing the average annual yield of hay per acre on each plot, reckoned from the commencement of the experiments to 1862 inclusive; the records for the plot giving the largest amount of produce standing at the head of the list, and so on, in order, according to the crop yielded. Side by side with these particulars, on their right, are given, for each plot, the proportion per cent. in the produce, of—

1.—Graminaceous herbage:
  Determined species;
  Undetermined stem and leaf;
  Shedded flowers, seeds, &c., chiefly Graminaceous.
2.—Leguminous herbage.
3.—Miscellaneous or weedy herbage.

Also the number of species, respectively of the Graminaceous, the Leguminous, and the Miscellaneous herbage.

It will be seen that the average annual amount of produce at the head of the list is 6877 lbs, and that there is a pretty gradual diminution down to 2720 lbs., which is the yield without manure of any kind. The heaviest produce was obtained where, in conjunction with the mixed mineral manure, the largest amount of ammonia-salts (containing about 164 lbs. of nitrogen) was applied. Leaving out of consideration for the present the comparatively immaterial influence of cut wheat-straw, or sawdust, the next in order as to amount of crop are the five plots where, with the mixed mineral manure, half the quantity of nitrogen (about 82 lbs.), either in the form of ammonia-salts or nitrate of

soda, was used. Then come two plots, the one with about 41 lbs. nitrogen, supplied in the form of ammonia-salts, and the other with the same amount in the form of nitrate of soda; the former with farmyard dung manure in addition, containing, of course, besides a large amount of mineral constituents and carbonaceous organic matter, a considerable quantity of nitrogen; the latter with the mixed mineral manure. Next comes the plot with ammonia-salts (=82 lbs. nitrogen) and superphosphate of lime instead of the mixed mineral manure, showing a deficiency of produce, due to the exclusion of the alkaline salts, of 1200 lbs. to 1400 lbs. per acre per annum. Still, this obviously defective combination gives more produce than an annual dressing of 14 tons of farmyard manure per acre, with all its mineral and carbonaceous organic matter, and a good deal of nitrogen also. Nitrate of soda alone = 82 lbs. nitrogen, stands next to farmyard manure alone, giving more produce than the mixed mineral manure alone; which, in its turn, gives slightly more than ammonia-salts alone = 82 lbs. nitrogen, or nitrate of soda alone = 41 lbs. nitrogen, and considerably more than superphosphate of lime alone. But although the mixed mineral manure alone gave more total produce than the ammonia-salts alone (= 82 lbs. nitrogen), it in point of fact gave very much less of Graminaceous herbage, its increase consisting in very large proportion of Leguminous plants.

The general result is, then, that the largest amounts of gross produce were obtained where the largest amounts of nitrogen were applied in the manure; provided only, that a sufficiency of mineral constituents was at the same time supplied. Further, that much larger crops were obtained by means of artificial manures supplying nitrogen and mineral constituents, than by a heavy dressing of farmyard manure, with all its carbonaceous organic matter in addition to its large amount of nitrogen and mineral constituents. And again, a complex mineral manure alone, gave about as much total produce as ammonia-salts alone or nitrate of soda alone; but the description of herbage developed was very different in the two cases.

Let us now consider the varying character of the herbage coincident with the use of such very different descriptions of manure, and the production of such very varying amounts of crop.

A glance at the Table (II.) shows that with the highest amount of produce there was the highest proportion in it of Graminaceous herbage = about 95 per cent., no Leguminous herbage whatever, and the lowest proportion of Miscellaneous herbage = not quite 5 per cent. There was also with the lowest amount of produce only about 74 per cent. of Graminaceous herbage (which is almost

TABLE II.—Showing the General Description, and Proportion per Cent., of the employed, and to the amounts of Crop

Order of most Produce, per Acre.			General Description	
			Per Cent.	
			Graminaceous.	
Plot Nos.	General Description of Manures.	Hay, per Acre per Annum; average of 7 Years, 1856-62.	Determined Species.	Undetermined Stem and Leaf.
		lbs.		
13*b*	Ammonia-salts = 164 lbs. nitrogen, and mixed mineral manure, including silicates	6877	81·95	8·88
13*a*	Ammonia-salts = 164 lbs. nitrogen, and mixed mineral manure (without silicates)	6876	80·91	5·69
10	Ammonia-salts = 82 lbs. nitrogen, and mixed mineral manure	6357	77·57	6·31
11	Ammonia-salts = 82 lbs. nitrogen, and mixed mineral manure (excluding potass in 1862), and sawdust	6216	72·97	8·91
12*a*	Ammonia-salts = 82 lbs. nitrogen, mixed mineral manure, and 2000 lbs. cut wheat-straw	6159	80·61	6·52
12*b*	Duplicate of plot 12*a* (half of the plot rather sheltered by trees)	6141	74·39	12·69
15	Nitrate of soda = 82 lbs. nitrogen, and mixed mineral manure	5783*	67·39	12·65
17	Ammonia-salts = 41 lbs. nitrogen, and farmyard manure	5468	73·48	5·82
14	Nitrate of soda = 41 lbs. nitrogen, and mixed mineral manure	4939*	65·78	8·27
3*b*	Ammonia-salts = 82 lbs. nitrogen, and superphosphate of lime	4877†	69·45	6·40
16	Farmyard manure, alone	4775	60·33	7·88
7	Nitrate of soda, alone = 82 lbs. nitrogen	4126*	52·34	17·65
9	Mixed mineral manure (excluding potass in 1862), and sawdust	4100	65·21	4·40
8	Mixed mineral manure, alone	3919	56·47	5·83
5	Ammonia-salts = 82 lbs. nitrogen, and sawdust	3839	77·43	1·59
6	Nitrate of soda, alone = 41 lbs. nitrogen	3805*	57·27	14·61
4	Ammonia-salts, alone = 82 lbs. nitrogen	3719	78·68	5·07
3*a*	Superphosphate of lime, alone	3164†	62·36	8·90
2	Unmanured	2927	58·13	11·61
1	Unmanured	2720	58·82	7·43

* Average of 5 years only, 1858-62 inclusive.
† Average of 4 years only, 1859-62 inclusive.

fferent kinds of Herbage, and the Number of Species, in relation to the Manures elded. SEVENTH SEASON, 1862.

HERBAGE.

Per Cent.				Number of Species.			
Graminaceous.		Leguminous.	Miscellaneous.	Graminaceous.	Leguminous.	Miscellaneous.	Total.
dded Flowers d Seeds, &c., iefly Graminaceous.	Total.						
4·19	95·02	0·00	4·98	14	0	7	21
3·81	90·41	0·00	9·59	15	0	9	24
5·78	89·66	0·12	10·22	14	2	12	28
4·96	86·84	0·13	13·03	15	2	13	30
3·25	90·38	0·46	9·16	14	2	13	29
5·06	92·14	0·02	7·84	14	2	10	26
9·71	89·75	0·86	9·39	13	2	10	25
10·28	89·58	0·21	10·21	16	4	8	28
5·64	79·69	1·92	18·39	15	3	13	31
7·63	83·48	0·11	16·41	13	3	16	32
10·86	79·07	1·72	19·21	13	3	11	27
10·32	80·31	0·17	19·52	16	2	10	28
3·97	73·58	18·28	8·14	16	4	16	36
4·10	66·40	24·09	9·51	17	4	19	40
3·25	82·27	0·24	17·49	16	4	15	35
12·34	84·22	0·32	15·46	15	3	13	31
4·59	88·34	0·15	11·51	16	3	14	33
7·46	78·72	2·60	18·68	16	4	19	39
4·25	73·99	6·16	19·85	15	3	20	38
7·95	74·20	7·61	18·19	16	4	23	43

almost the lowest proportion), about 7 per cent. of Leguminous herbage, and nearly the highest proportion of Miscellaneous or weedy herbage.

Again, whilst the smallest number, or only 21 species of plants, was discovered in the sample of the heaviest produce, the largest number, or 43 species, was found in that of the smallest produce.

These extreme results prominently bring to view the fact, that with large produce there was an almost exclusively Graminaceous, and a comparatively simple herbage; and that with small produce the herbage was at once much less Graminaceous, and much more complex. There is, moreover, with some instructive exceptions to which attention will be directed, something like a gradual decrease in the proportion of Graminaceous, and increase in that of the Miscellaneous herbage, and especially in the number of species, as we proceed from the larger to the smaller crops.

Taking the results given in the Table a little more in detail, it will be well to bear in mind the general character of the herbage on the unmanured land, as the standard by which to compare that on the variously manured plots.

The unmanured produce, taking the mean result of the two plots, consisted, in round numbers, of about 74 per cent. Graminaceous, 6 to 7 per cent. Leguminous, and about 19 per cent. Miscellaneous herbage; and it comprised about 40 species of plants.

In contrast with the above composition, that of the six or seven heaviest crops at the head of the list in the Table (II.) may be taken, in round numbers, at from about 90 to 95 per cent. Graminaceous, from 0 to 0·86 per cent. Leguminous, and from 5 to something over 10 per cent. Miscellaneous herbage; the number of species varying from 21 to 30.

Comparing these heavier crops with one another, it is interesting to observe that Plot 13 *b*, manured with ammonia-salts and a mineral manure including silicates, gave a higher percentage of Graminaceous, and a lower percentage of Miscellaneous herbage, than Plot 13 *a*, with otherwise the same manure but excluding silicates. Again, Plot 10 with ammonia-salts and mineral manure including potass, gave rather more produce, and a rather higher proportion of Graminaceous herbage, than Plot 11, with the same amount of ammonia-salts, and otherwise the same mineral manure (and sawdust in addition), but excluding potass. Plot 10 also gave rather more produce than either Plot 12 *a* or Plot 12 *b*, which had the same amount of ammonia-salts and mineral manure, with 2000 lbs. of cut wheat-straw per acre per annum in addition, though these plots with the cut wheat-straw gave a slightly higher proportion of Graminaceous herbage.

Plot 15, with the same mineral manure as Plot 10, and with

about the same amount of nitrogen, but in the form of nitrate of soda instead of ammonia-salts, gave considerably less produce but almost exactly the same proportion of Graminaceous herbage, and more Leguminous herbage (0·86 per cent.), than any of the plots manured with ammonia-salt.

The better adaptation of nitrate of soda than ammonia salts as a manure for Leguminous plants, a fact which we have in other cases observed, is again seen in the results of Plot 14. In that case, with a smaller amount of nitrate of soda and the mixed mineral manure, the Leguminous herbage amounted to nearly 2 per cent. of the produce. There was, at the same time, a larger proportion of Miscellaneous or weedy herbage (18·39 per cent.), and consequently a smaller proportion of the Graminaceous, than in any other case with an equally bulky crop. Ammonia-salts, even in conjunction with farmyard-manure, increased the proportion of Graminaceous plants at the expense of the Leguminous and Miscellaneous herbage.

Farmyard-manure alone, increased the proportion of the Graminaceous at the expense of the Leguminous herbage, the proportion of Miscellaneous herbage remaining about the same, though its character was very different, there being much fewer species and much greater predominance of individual weeds. In fact, under the influence of farmyard-manure there were fewer species developed within each division—Graminaceous, Leguminous, and Miscellaneous—the manured crop affording only 27 species, against 38 in one case, and 43 in another, without manure.

Perhaps the most striking of the results recorded in the Table is that obtained on Plot 8, by means of the mixed mineral manure alone. Whereas, without manure we have 74 per cent. Graminaceous, 6 to 7 per cent. Leguminous, and nearly 20 per cent. Miscellaneous herbage; and with the mixed mineral manure, *and ammonia-salts in addition*, 90 to 95 per cent. of the produce Graminaceous, either no Leguminous herbage at all, or but a fraction of 1 per cent. of it, and 5 to 10 per cent. of Miscellaneous herbage; we have, with mixed mineral manure *alone*, only about 66½ per cent. of Graminaceous herbage, as much as 24 per cent. Leguminous herbage, and only about 9½ per cent. Miscellaneous. Thus, two-thirds only of the produce by the mixed mineral manure alone consisted of grasses, whilst nearly one-fourth of it consisted of clovers, meadow vetchling, and trefoil. The total number of species was, however, about as high as without manure, and very much higher than with the same mineral manure and ammonia-salts in addition.

As already alluded to, when such mineral manures are applied to crops grown separately, as in rotation, instead of together in a

mixed herbage, they generally increase the produce of Graminaceous ones but little, and that of Leguminous ones very characteristically. It has been found, too, that even in a clayey soil, the constituent of mineral manures which seems to have the most influence upon the growth of the Leguminous plants of rotation, beans and clover for example, was potass; and we have in the results under consideration a striking instance of the effects produced on the growth of the allied plants of the mixed herbage by a liberal supply to the soil of that constituent. Thus, Plot 9 had in every previous year of the experiments received the same description and amount of mineral manure as Plot 8, but in 1862 the potass was excluded (from Plot 9), and a larger amount of soda-salt substituted. The result was that the produce of Plot 9, without the potass, gave only 18 instead of 24 per cent. of Leguminous herbage, or only three-fourths as high a proportion as that of the plot manured otherwise similarly, but with the potass in addition.

Superphosphate of lime alone, used for a series of years, has somewhat increased the amount and proportion of the grasses, at the expense of the Leguminous plants; the proportion of the Miscellaneous herbage remaining about the same. Still, the proportion of the Leguminous herbage under the influence of this manure, though considerably less than without manure, and little more than one-tenth as great as with the mixed mineral manure (containing salts of potass, soda, and magnesia, as well as superphosphate of lime), was considerably greater than in any case where either ammonia-salts or nitrates were used, whether they were employed alone, in combination with mixed mineral, or with farmyard-manure.

Lastly, ammonia-salts alone (or with only sawdust in addition), or nitrate of soda alone, considerably increased the proportion of the grasses, almost excluded the Leguminous herbage, reduced the proportion of Miscellaneous plants, and also the total number of species.

It will perhaps be remembered that some years ago Baron Liebig stated he had obtained marked effects by the use of sawdust as a manure; a result which he considered due to the evolution of carbonic acid from the decomposing sawdust, by means of which the supply of mineral constituents within the soil was rendered more rapidly available.

We have, therefore, for some years past, applied 2000 lbs. of sawdust per acre, per annum, to a few of the experimental plots. Where, in previous years, the sawdust was used, either alone, with mineral manure without ammonia-salts, or with ammonia-salts without mineral manure, some, but generally a very small increase of produce, has been the result. But where the sawdust has been

employed with both mineral manure and ammonia-salts, that is to say with a combination itself yielding a pretty full increase of produce, no further increase has been obtained by its means. Nor has the use, annually, of 2000 lbs. of finely-cut wheat-straw, in addition to the mixture of mineral manure and ammonia-salts, had as yet any beneficial effect upon the amount of gross produce per acre, notwithstanding the large amount of mineral matter peculiarly adapted for the growth of Graminaceous plants, which, in addition to its decomposing carbonaceous substance, it would in the course of time supply.

Sawdust has, for similar reasons, also been tried on some of the crops grown on land under tillage, and with equal failure of beneficial result.

So far as observation goes, the effects of sawdust have been as immaterial on the character of the mixed herbage as on its amount; but as in the past season, 1862, in two out of the three cases where sawdust was employed potass was excluded from the mixed mineral manure used with it, the results are not, in the season in question, strictly comparable with those of the plots with which they had previously been compared, but which now differ not only in not having sawdust, but in having potass. The only strictly comparable experiments in 1862 are that of Plot 4 with ammonia-salts alone, and that of Plot 5 with the same amount of ammonia-salts, and sawdust in addition; and, so far as the figures go, it would appear that the sawdust somewhat reduced the proportion of the grasses, and increased that of the Miscellaneous or weedy herbage.

We now turn to a consideration of the next branch of the subject.

II.—*The description, and proportion per cent., of the predominating species, in relation to the manures employed, and to the amounts of crop yielded.*

Table III. (pp. 18-19) illustrates this branch of the subject. As in Table II., the plots are arranged in order according to the amount of produce, the one yielding the most being at the head of the list, and so on. The particulars given relating to the predominating plants are—

1. The names, and proportion per cent., of the 5 predominating Graminaceous plants, or genera.
2. The names, and proportion per cent., of the 2 predominating Leguminous plants, or genera.
3. The same particulars for the 3 predominating Miscellaneous or weedy plants.

Although it is believed that the figures in the various Tables may

TABLE III.—Showing the Description, and Proportion per Cent., of the predominati

SEVENT

Order of most Produce, per Acre.			Description, and per Cen			
			The Five predominati			
Plot Nos.	General Description of Manures.	Hay, per Acre per Annum; average of 7 Years, 1856–62.	1	2	3	4
		lbs				
13*b*	Ammonia-salts = 164 lbs. nitrogen, and mixed mineral manure (including silicates)	6877	Dactylis gl. 21·9	Agrostis vul. 19·3	Poa tr. & pr. 14·3	Holcus lan. 7·0
13*a*	Ammonia-salts = 164 lbs. nitrogen, and mixed mineral manure (without silicates)	6876	Dactylis gl. 23·6	Poa tr. & pr. 16·6	Agrostis vul. 9·2	Holcus lan. 8·8
10	Ammonia-salts = 82 lbs. nitrogen, and mixed mineral manure	6357	Avena p. & f. 18·1	Poa tr. & pr. 12·7	Lolium per. 11·9	Agrostis vul 11·6
11	Ammonia-salts = 82 lbs. nitrogen, and mixed mineral manure (excluding potass in 1862), and sawdust	6216	Avena p. & f. 19·2	Dactylis gl. 11·9	Poa tr. & pr. 9·1	Holcus lan. 8·6
12*a*	Ammonia-salts = 82 lbs. nitrogen, mixed mineral manure, and 2000 lbs. cut wheat-straw	6159	Dactylis gl. 23·6	Avena p. & f. 12·6	Agrostis vul. 12·0	Poa tr. & pr. 9·0
12*b*	Duplicate of Plot 12*a* (half of the plot rather sheltered by trees)	6141	Dactylis gl. 31·0	Poa tr. & pr. 12·0	Holcus lan. 6·3	Festuca p. & d 6·3
15	Nitrate of soda = 82 lbs. nitrogen, and mixed mineral manure	5783*	Poa triv. 17·1	Dactylis gl. 11·6	Lolium per. 10·0	Bromus mol. 9·4
17	Ammonia-salts = 41 lbs. nitrogen, and farmyard manure	5468	Poa tr. & pr. 29·5	Dactylis gl. 16·9	Bromus mol. 12·5	Holcus lan. 6·0
14	Nitrate of soda = 41 lbs. nitrogen, and mixed mineral manure	4939*	Avena f. & p. 17·8	Festuca d. & p. 11·1	Agrostis vul. 10·3	Holcus lan. 9·6
3*b*	Ammonia-salts = 82 lbs. nitrogen, and superphosphate of lime	4877†	Agrostis vul. 18·6	Holcus lan. 15·3	Avena p. & f. 8·4	Poa triv. 7·3
16	Farmyard manure, alone	4775	Poa triv. 27·4	Bromus mol. 9·6	Avena p. & f. 7·3	Dactylis gl. 4·9
7	Nitrate of soda alone = 82 lbs. nitrogen	4[illegible]*	Festuca d. & p. 16·0	Alopecurus pr. 6·9	Agrostis vul. 6·2	Avena p. & f. 6·0
9	Mixed mineral manure (excluding potass in 1862), and sawdust	4100	Avena p. & f. 47·7	Festuca d. & p. 9·9	Agrostis vul. 7·6	Lolium per. 7·0
8	Mixed mineral manure, alone	3919	Avena p. & f. 16·7	Festuca d. & p. 12·8	Poa tr. & pr. 6·7	Arrhenath. av 5·3
5	Ammonia-salts = 82 lbs nitrogen, and sawdust	3839	Agrostis vul. 20·5	Avena p. & f. 16·6	Festuca d. & p. 14·4	Holcus lan. 8·1
6	Nitrate of soda, alone = 41 lbs. nitrogen	3805*	Alopecurus pr. 19·7	Festuca d. & p. 8·0	Agrostis vul. 6·8	Holcus lan. 6·7
4	Ammonia-salts, alone = 82 lbs. nitrogen	3719	Festuca d. & p. 23·3	Agrostis vul. 21·3	Holcus lan. 9·7	Avena p. & f. 8·5
3*a*	Superphosphate of lime, alone	3164†	Avena p. & f. 12·5	Festuca d. & p. 12·2	Holcus lan. 11·9	Lolium per. 9·5
2	Unmanured	2927	Festuca p. & d. 16·2	Avena p. & f. 11·3	Agrostis vul. 5·5	Dactylis gl. 5·2
1	Unmanured	2720	Festuca p. & d. 13·9	Avena p. & f. 11·0	Lolium per. 8·7	Agrostis vul. 8·6

* Average of 5 years only, 1858-62 inclusive.
† Average of 4 years only, 1859-62 inclusive.

Species, in relation to the Manures employed, and to the Amounts of Crop yielded. Season, 1862.

OF PREDOMINATING SPECIES.

Graminaceous Plants.		The Two predominating Leguminous Plants.			The Three predominating Miscellaneous Plants.			
5	Total per Cent.	1	2	Total per Cent.	1	2	3	pe
Arrhenath. av. 5·7	68·2	0·00	0·00	0·00	Rumex acet. 3·72	Carum Car. 0·82	Achillæa mil. 0·39	
Lolium per. 8·6	66·8	0·00	0·00	0·00	Rumex acet. 6·40	Achillæa mil. 1·53	Carum Car. 1·35	
Holcus lan. 11·1	65·4	Lathyrus pr. 0·11	Trifolium rep. 0·01	0·12	Rumex acet. 4·93	Carum Car. 2·34	Achillæa mil. 1·96	
Agrostis vul. 8·0	56·8	Lathyrus pr. 0·12	Trifolium rep. 0·01	0·13	Rumex acet. 9·26	Carum Car. 1·47	Achillæa mil. 0·90	
Lolium per. 7·5	64·7	Lathyrus pr. 0·41	Trifolium pr. 0·05	0·46	Rumex acet. 4·88	Achillæa mil. 2·08	Carum Car. 1·74	
Avena p. & f. 6·0	61·6	Lathyrus pr. 0·01	Trifolium rep. 0·01	0·02	Rumex acet. 5·51	Carum Car. 1·33	Achillæa mil. 0·75	
Holcus lan. 6·7	54·8	Lathyrus pr. 0·84	Trifolium pr. 0·02	0·86	Rumex acet. 7·09	Carum Car. 1·09	Ranun. a. & b. 0·52	
Avena f. & p. 3·8	68·7	Lathyrus pr. 0·14	Trifolium pr. 0·05	0·19	Rumex acet. 5·76	Achillæa mil. 1·39	Ranun. a. & b. 1·39	
Poa triv. 7·3	56·1	Trifol. p. & r. 1·87	Lathyrus pr. 0·05	1·92	Rumex acet. 5·33	Ranun. a. & b. 5·18	Carum Car. 3·75	
Festuca d. & p. 6·9	56·5	Lathyrus pr. 0·07	Trifol. p. & r. 0·04	0·11	Rumex acet. 11·05	Ranun. a. & b. 1·73	Achillæa mil. 1·70	
Arrhenath. av. 2·7	51·9	Lathyrus pr. 0·90	Trifol. p. & r. 0·82	1·72	Rumex acet. 10·33	Ranun. a. & b. 2·34	Achillæa mil. 2·34	
Lolium per. 4·6	39·7	Trifolium pr. 0·16	Lotus cornic. 0·01	0·17	Plantago lanc. 6·99	Rumex acet. 5·72	Achillæa mil. 2·55	
Arrhenath. av. 5·1	47·3	Trifol. p. & r. 10·01	Lathyrus pr. 8·10	18·11	Rumex acet. 1·70	Carum Car. 1·39	Achillæa mil. 0·95	
Holcus lan. 4·9	46·4	Lathyrus pr. 13·24	Trifolium pr. 7·51	20·75	Rumex acet. 1·86	Carum Car. 1·79	Achillæa mil. 1·69	
Lolium per. 5·8	65·4	Lathyrus pr. 0·22	Trifolium pr. 0·01	0·23	Rumex acet. 10·64	Achillæa mil. 3·37	Galium ver. 0·95	
Poa tr. 5·7	46·9	Trifolium pr. 0·28	Lotus cornic. 0·03	0·31	Centaurea nig. 3·93	Plantago lanc. 3·06	Rumex acet. 2·84	
Arrhenath. av. 5·8	68·6	Lotus cornic. 0·07	Trifolium pr. 0·07	0·14	Rumex acet. 7·88	Achillæa mil. 1·33	Carum Car. 0·86	
Poa tr. & pr. 5·7	51·8	Trifol. p. & r. 1·93	Lotus cornic. 0·39	2·32	Plantago lanc. 5·35	Ranun. a. & b. 4·27	Rumex acet. 3·17	
Holcus lan. 4·8	43·0	Trifolium pr. 2·66	Lathyrus pr. 1·88	4·54	Plantago lanc. 7·72	Rumex acet. 2·68	Carum Car. 2·52	
Holcus lan. 5·0	47·2	Trifol. p. & r. 4·73	Lotus cornic. 1·69	6·42	Plantago lanc. 6·87	Ranun. a. & b. 3·61	Luzula camp. 1·54	

c 2

may be fully relied upon as showing the general relation to one another of the individual species, or different orders of plants, it is by no means supposed that small numerical differences, or even in all cases greater ones, are to be taken unconditionally as representing corresponding differences in the character of the herbage. It will be readily understood that in any case, and especially in that of a very heavy and luxuriant crop, there must be great difficulty in collecting a sample of no more than some ten pounds weight which will absolutely represent the bulk of the mixed herbage. Then again, the difficulty of separation and identification in the case of a mass of ill-defined and mutilated leafy produce is extremely great. It was with a full appreciation of these difficulties that we felt it necessary, if for no other reason than as a means of control over the numerical results, that the several series of notes to which reference has been made should be taken. And although the botanical separations have been conducted at the cost of an immense amount of care and labour, we shall, in the few remarks we have to make on the results on the present occasion, be guided by a careful consideration of the recorded observations, as well as of the figures given in the tables.

Taking the distribution of plants in the produce of the unmanured land as the standard by which to compare that of the other plots, attention will be directed in some detail to its components.

The Unmanured produce.

Sixteen Graminaceous species were identified in the unmanured produce, constituting together about 74 per cent. of its weight; and although their distribution was more even than in most of the cases of the manured land, the species of the five predominating genera amounted in one case to 43 and in another to 47 per cent. of the total produce. In the produce of the heaviest crops, however, generally over 60, and sometimes as much as 68 or 69 per cent. were referable to the five predominating species, or at any rate to the species included within the five predominating genera.

In the unmanured produce, Festuca duriuscula, or F. pratensis, which are hardy and good grasses, Avena pubescens and A. flavescens, sweet and good grasses, adapted to dry and chalky land, and much liked in hay, were the most prominent; but they were by no means in such large proportion as the predominating grasses on most of the manured plots. Next to these were Lolium perenne, a very good and free-growing grass; Agrostis vulgaris, a creeping-rooted plant, said to be not liked by cattle; and Holcus lanatus, also a bad food-grass, being too soft and woolly. After these came Arrhenatherum avenaceum, a rather favourite

grass as early feed, and for its second cut; Poa trivialis, also a good grass for early feed and second crop, but from its tufty growth and strong creeping roots said to be apt to banish other grasses; Anthoxanthum odoratum, a fragrant grass, but not relished in large quantity; and Alopecurus pratensis, better as green food than as hay. All the above were more evenly distributed in the small unmanured produce than in any other; and it contained besides, insignificant quantities of Dactylis glomerata, a bulky and free-growing grass under favourable conditions, and much liked by stock when not too old; Briza media, a plant of limited growth, and not much relished as food; Cynosurus cristatus, varying in character considerably, according to circumstances of growth, better for pasture than for hay, but upon the whole of little utility; and lastly Bromus mollis, a soft and very bad food-grass.

It is true that on one of the unmanured plots (No. 2) Dactylis glomerata occurred in notable quantity; but as that plot was situated between plots 12 *a* and 13 *b*, on both of which Dactylis was very luxuriant, it is more probable that it has, from time to time, been seeded from them, than that such a grossly-feeding grass flourished naturally on the unmanured land. Observation, indeed, led to the conclusion that in some other cases unexpected differences in the indications of the figures are attributable to adventitious circumstances of an allied kind.

Of Leguminous herbage, the unmanured produce contained from 6 to 7 per cent., the larger portion of which consisted of perennial red clover, with a little white clover. Lathyrus pratensis (meadow vetchling), and Lotus corniculatus (bird's-foot trefoil) occurred in less quantity, but the two about equally, and more largely than in any other case excepting where the mixed mineral manures were employed.

The Miscellaneous or weedy herbage, of which nearly 20 per cent. of the unmanured produce was composed, also consisted, like the Graminaceous herbage, of a great variety of species, of which few specially predominated, excepting the Plantago lanceolata (ribwort plantain). The next in prominence were the Ranunculus acris and R. bulbosus (crowfoots), Rumex acetosa (sorrel dock), Carum Carui (common caraway), Achillæa millefolium (milfoil), and Luzula campestris (field wood-rush). In smaller quantity occurred—of the Order *Compositæ*—Centaurea nigra (black knapweed), Leontodon hispidus (rough hawkbit), Tragopogon pratense (yellow goat's beard), Taraxacum Dens-leonis (dandelion), Hypochœris radicata (cat's-ear), and Bellis perennis (daisy); of the Order *Umbelliferæ*, Pimpinella saxifraga (burnet saxifrage), and Heracleum sphondylium (hogweed); and of plants of various other natural Orders, occurring still less pre-

valently, were the Veronica chamædrys (germander speedwell), Cerastium vulgatum (mouse-ear chickweed), Stellaria graminea (lesser starwort), Scabiosa arvensis (field scabious), Hypnum squarrosum (squarrose moss), Primula veris (cowslip), Sanguisorba officinalis (great burnet), Geum urbanum (common avens), Galium verum (yellow bed-straw), Ajuga reptans (bugle), and Ophioglossum vulgatum (adder's tongue). Aud there were probably others of too unpretending and restricted growth to be observed on the ground, or to come within reach of the scythe.

Upon the whole the unmanured produce—Graminaceous, Leguminous, and Miscellaneous—was more complex, and less characterised by the prevalence of individual species, than that of any of the manured plots. The most predominating plants were, of the grasses Festuca duriuscula and F. pratensis, Avena pubescens and A. flavescens; and of the Miscellaneous or weedy plants, Plantago lanceolata.

It is only necessary to add that the meadow yielding the mixed herbage composed as above described, though giving hay of fair average quality, and useful after-feed for store stock, or sheep, by no means partakes of the character of a fattening pasture.

Effects of Mineral Manures alone.

The plots on which the Graminaceous herbage more nearly approached to that of the unmanured land, both in complexity and in general prevalence of the same species, were plot 3 *a* manured with superphosphate of lime alone, and plots 8 and 9 with the mixed mineral manure. The chief distinctions apparent are, that by superphosphate of lime alone the inferior grass Holcus lanatus was brought into somewhat greater prominence, and that by it, as well as by the mixed mineral manure alone, the useful grass Poa trivialis was somewhat increased in relative amount. By the mixed mineral manure, Arrhenatherum avenaceum also appears to be somewhat encouraged. The free growing and bulky Dactylis glomerata was in very small quantity on either of the plots manured with mineral manure alone; nor are either of the other grasses which occur in predominating amount on one or other of the plots yielding the heavier crops, found at all prominently in the comparatively small produce grown under the influence of mineral manures alone.

It was on the amount and character of the Leguminous herbage that the mineral manures alone produced the most striking effects. Superphosphate of lime alone, considerably reduced the proportion of such herbage; but when with it salts of potass, soda, and magnesia were used, Trifolium pratense perenne, and Lathyrus pratensis, were developed in an extraordinary degree. When the

mixed mineral manure contained potass, as well as soda and magnesia (plot 8), the Lathyrus somewhat predominated; and where the potass was excluded (plot 9) it was in a smaller proportion. Lotus, again, was more abundant on plot 8, where the potass was employed. As already alluded to, however, the total amount of Leguminous herbage was very much the less on plot 9, where the potass was excluded; and as at present it has only been for one season excluded, it is not improbable that the proportion of such herbage will in future be greatly reduced. It is worthy of remark, too, that on plot 8, where the application of potass is continued, the proportion of Leguminous herbage was almost exactly the same in the produce of the seventh year of the experiments, 1862, as it had been found to be in that of the third season, 1858.

Superphosphate of lime alone, which tended to decrease the proportion of Leguminous plants, seemed to be generally favourable to the development of the Miscellaneous ones, both the variety and amount of such herbage being considerable. The proportion of Plantago lanceolata was nearly as great as on the unmanured plot, and that of Ranunculus (acris and bulbosus), Rumex, Achillæa, and Carum Carui, was also comparatively large. On the other hand, the mixed mineral manures, which so much increased the proportion of the Leguminous plants, considerably diminished that of the Miscellaneous ones. The variety of such herbage was, however, considerable; the reduction in amount being due to the diminished luxuriance of several species, and especially the Plantago, which was in very small amount.

Effects of Ammonia-Salts alone.

Compared with the unmanured produce, ammonia-salts alone, or with sawdust only in addition, considerably increased the proportion of total Graminaceous herbage, and also the amount referable to the species of the five predominating genera, the latter reaching from 65 to 68 per cent. of the total produce. To a great extent, however, the same grasses prevailed as in the small crops without manure, or with mineral manures alone. The most prominent effect of this relatively excessive nitrogenous condition, was the encouragement of the Festuca duriuscula and Avena pubescens, two good elements predominating in the produce without manure; to a greater extent still that of the objectionable creeping-rooted Agrostis; and in some degree also that of the inferior Holcus lanatus. Compared with the effects on the distribution of the Graminaceous herbage of mineral manure alone, the most marked result of the ammonia-salts alone was the great increase of the Agrostis and the Holcus, at the

expense, to some extent, of the superior Poa trivialis, but in a greater degree of the Leguminous herbage. The free growing and bulky Dactylis, as by mineral manures alone, so also by ammonia-salts alone (which characteristically favour the growth of Graminaceous herbage generally), appears to be kept in the background. In fact, although the increase by ammonia-salts alone was exclusively Graminaceous (other plants being actually reduced in amount), it was also almost exclusively composed of the leafy herbage of the less grossly growing grasses.

Under the influence of ammonia-salts alone the produce did not contain a quarter of 1 per cent. of Leguminous herbage.

The proportion of total Miscellaneous plants, and the number of species, were reduced by the use of ammonia-salts alone; but some few plants were very strikingly encouraged, especially the Rumex acetosa, which was both abundant and luxuriant. Carum Carui was also very prevalent, more so than the figures would indicate; the small weight being probably due to its being ripe, and having shedded much seed before being cut. Achillæa millefolium was also a very prominent plant; and Luzula campestris was more so than on most of the manured plots.

Effects of Nitrate of Soda alone.

The effects of nitrate of soda alone, though in many respects similar to those of ammonia-salts alone, show some peculiarities. The proportion of the total herbage referable to the five predominating Graminaceous genera is unusually small; whilst a plant occurring in the produce without manure in very small quantity, and in less amount still in that by mineral manure alone, or ammonia-salts alone, comes here into very great prominence. This grass, Alopecurus pratensis (fox-tail grass), a good pasture plant, but not a good element in hay, contributed 19·7 per cent. to the produce where the smaller amount of nitrate of soda was used alone, and nearly 7 per cent. where the larger amount was employed; though, in only one other case, excepting in the produce without manure, did it exceed 2 per cent. This grass was, in fact, quite characteristic of the nitrated plots. Otherwise, there was a pretty equal distribution of the grasses prevailing on the plots hitherto considered; though, as with ammonia-salts without mineral manure, there was here a great tendency to development of foliage from the base, rather than to the growth of stem and stem-leaves.

Nitrate of soda alone, like ammonia-salts alone, very much discouraged the Leguminous herbage. Lathyrus and Lotus were almost totally excluded; and Trifolium only contributed about a quarter of 1 per cent. of the produce.

Unlike ammonia-salts alone, the nitrate of soda seemed to encourage the Plantago lanceolata; and under its influence Centaurea nigra and Taraxacum Dens-leonis, though in small amount, were somewhat more prominent than usual. But next to Plantago lanceolata, Rumex acetosa, Achillæa millefolium, Ranunculus (acris and bulbosus), and Carum Carui were the most abundant of the Miscellaneous plants, though none of them were very luxuriant. The total amount of Miscellaneous herbage was comparatively large, but resulted from the great frequency of some few species, rather than from either great variety, or great luxuriance of any particular plants.

Effects of Farm-Yard Manure alone.

Farmyard dung alone, the manure upon which dependence must to a great extent be placed for grass-land devoted to the production of hay, gave a produce containing 79 per cent. of total Graminaceous herbage, but a comparatively small proportion (51·9 per cent.) referable to the five predominating genera; and this was the case notwithstanding that one grass, Poa trivialis, which was not at all prominent on any of the plots already considered, contributed 27½ per cent. of the total herbage as sampled. The notes taken on the ground agree with the figures in showing this plant to have been very prominent; and, as will presently be seen, it also occurred in very predominating amount on the plot manured with farmyard-manure and ammonia-salts. So far farmyard-manure improves the character as well as increases the amount of the Graminaceous herbage; but it also brings into greater prominence than any of the other manures Bromus mollis, which is reputed to be a very bad food-grass. It, at the same time, encourages the free-growing, productive, and, upon the whole, good but somewhat coarse grass Dactylis glomerata more than any of the manures yielding the smaller crops. The three grasses Poa trivialis, Bromus mollis, and Dactylis glomerata, which are thus seen to be increased in their development by farmyard-manure, are so at the cost chiefly of Festuca duriuscula and F. pratensis, but partly of Avena pubescens and Agrostis vulgaris, and in a less degree of some other grasses.

The produce by farmyard-manure contained a much less amount and proportion of Leguminous herbage than that without manure; both Trifolium and Lathyrus being much reduced, and Lotus excluded, at any rate from the mown sample. This result is probably due more to the increased luxuriance of the grasses and certain Miscellaneous plants, by which the Leguminous ones are displaced, than to any directly injurious effect of the farmyard-manure; for the notes taken on the ground show that

although Trifolium and Lathyrus were less frequent on the farmyard-manure than on the unmanured plot, they were on the other hand more luxuriant.

The Miscellaneous or weedy plant most prominently developed by farmyard-manure was the Rumex acetosa, or sorrel dock, which amounted to rather more than 10 per cent. of the sample examined; though, from the notes taken on the ground, it is concluded that the sample perhaps included a somewhat undue proportion. According to the notes, Carum Carui was by far the most frequently occurring weed. Ranunculus (acris and bulbosus), and Achillæa millefolium were also each very frequent; and Plantago lanceolata was more so than in most of the crops of equal bulk. Besides those mentioned, scarcely any other weedy plants occurred; there being a large total percentage of Miscellaneous herbage, but referable to comparatively few species, and it was the frequency rather than the luxuriance of these that contributed to the large amount.

Effects of Farmyard-manure and Ammonia-Salts.

As already alluded to, the combination of farmyard-manure and ammonia-salts, like farmyard-manure alone, very strikingly developed the Poa trivialis, and to a considerable extent the Bromus mollis also. The chief distinction is, that the ammonia-salts used in conjunction with a manure supplying a large amount of mineral matter, strikingly increases the growth of the Dactylis glomerata, apparently at the expense of the Miscellaneous herbage, of which there were but very few species, and but a small amount, whilst the proportion of total Graminaceous herbage was considerably increased. In other respects, the produce was very similar in its Graminaceous components to that by farmyard-manure alone; there being, in the two cases, besides the grasses which have been specially noticed, pretty equal proportions of most of those occurring on the unmanured plot. Holcus lanatus was, however, rather more plentiful and luxuriant where the ammonia-salts were used.

Under the influence of ammonia-salts in conjunction with farmyard-manure all the elements of Leguminous herbage were almost as completely excluded as when ammonia-salts were used alone.

The number of species of Miscellaneous plants was unusually small under the conditions of manuring now in question; and the proportion in the produce of such herbage was also small. As in the case of farmyard-manure alone, Rumex acetosa was the most prominent weed. Judging from the notes and figures together, Carum was probably next in order of prevalence; and after it

came Ranunculus (acris and bulbosus), and Achillæa millefolium. But none of the Miscellaneous plants enumerated were so abundant here as under the influence of farmyard-manure alone; still, the amounts recorded in the Tables are attributable rather to their frequency than to great luxuriance.

Effects of Ammonia-Salts and Superphosphate of Lime.

Ammonia-salts in conjunction with superphosphate of lime, gave considerably more produce, a larger proportion of Graminaceous herbage, and a larger proportion referable to the five predominating Graminaceous genera than superphosphate of lime alone: the proportion of the latter being increased from 51 to 56½ per cent. of the total produce. The proportions of Poa trivialis and Lolium perenne are not much affected by the addition of the ammonia-salts; but those of Festuca duriuscula, Avena pubescens, and A. flavescens are considerably reduced; whilst the inferior grasses, Agrostis vulgaris and Holcus lanatus (especially the former), are brought into very considerable prominence. Although, therefore, the amount of produce was much increased by the addition of the ammonia-salts, the character of the Graminaceous plants developed was somewhat inferior. Dactylis glomerata was not encouraged by the combination in question.

As in other cases where nitrogenous manures were freely employed, Leguminous herbage of all kinds was almost excluded.

Of Miscellaneous herbage—as under somewhat similar conditions in other cases—Rumex acetosa was by far the most prominent element, being both very abundant and very luxuriant. Carum Carui was likewise both abundant and luxuriant, but had shedded a good deal of its seed; Ranunculus acris and R. bulbosus were frequent rather than luxuriant; Achillæa millefolium occurred in notable quantity; other Miscellaneous species were somewhat few in number and insignificant in amount.

Effects of Nitrate of Soda and mixed Mineral Manure.

By nitrate of soda and mixed mineral manure together, both the amount of produce and the proportion of it referable to the few predominating Graminaceous species were greater than by either nitrate of soda alone or mixed mineral manure alone. Where the smaller amount of nitrate of soda was used with the mixed mineral manure, Avena flavescens, Holcus lanatus, and Poa trivialis were the predominating grasses; and, according to the figures, Festuca duriuscula and Agrostis vulgaris were also in large amount, though the notes taken on the ground did not lead

to the conclusion that they were predominating. All these grasses occurred in larger amount than where the nitrate of soda was used alone. But the most remarkable effect of the addition of the mixed mineral manure was the almost entire exclusion of the Alopecurus pratensis, which had flourished in such an extraordinary degree under the influence of the nitrate of soda alone, and the great development in its stead of the Avena flavescens, which under the latter condition had occurred in very insignificant amount. With twice the amount of nitrate of soda and the same mixed mineral manure, the distribution of Graminaceous species was again very strikingly but very differently affected. Poa trivialis was now the predominating species; and Dactylis glomerata, Lolium perenne, and Bromus mollis were also in considerable quantity; Holcus lanatus coming next in order. Here again Alopecurus pratensis—the characteristic plant with nitrate of soda alone—was almost excluded; whilst Festuca duriuscula was reduced to a very insignificant amount, and Avena flavescens —so luxuriant with the smaller amount of nitrate and mineral manure—was here by no means prevalent. With regard to the great prominence of Poa trivialis and Bromus mollis on the plot now under consideration, it is, however, worthy of remark that it adjoined Plot 17, manured with farmyard-manure and ammonia-salts, where these two grasses were the characteristic plants. It would seem probable, therefore, that the result was, at any rate partly, due to seeding from the farmyard-manure plots, and hence so far accidental.

Of Leguminous plants, there was a somewhat larger proportion than by nitrate of soda alone, or by ammonia-salts either alone or in combination with the mixed mineral manure, though much less, especially of Trifolium, where the larger than where the smaller amount of nitrate of soda (with the mineral manure) was used, and in both cases very much less than without manure. The Lathyrus was more frequent than the Lotus: the latter, indeed, was all but wanting.

The amount and character of development of the Miscellaneous herbage differed very greatly on the two plots with nitrate of soda and mineral manure, both the proportion and the luxuriance being generally much greater with the smaller amount of nitrate. With the smaller amount of nitrate, Rumex acetosa, Ranunculus (acris and bulbosus), Carum Carui, and Achillæa millefolium were all both frequent and luxuriant, and Plantago lanceolata was somewhat so. With the larger amount of nitrate, Rumex acetosa was by far the most frequent and abundant weed; neither Achillæa millefolium nor Plantago lanceolata was at all prevalent; whilst Carum Carui and Ranunculus (acris and bulbosus), though somewhat frequent, were not luxuriant; and other weeds

were small both in number and amount. The general result is, that with the larger amount of nitrate and the mixed mineral manure—as with the corresponding amount of ammonia-salts and mixed mineral manure—both the number of species and the total amount of Miscellaneous plants were comparatively small.

Effects of Ammonia-Salts and mixed Mineral Manure.

There remain to be noticed, the distribution and predominance of species, on Plots 10, 11, 12*a*, 12*b*, 13*a*, and 13*b*, on which both ammonia-salts and mixed mineral manure were employed, and on which by far the largest crops were obtained.

Excepting in the case of Plot 11, where in 1862 potass was excluded from the mineral manure, the produce contained from 89½ to 95 per cent. of Graminaceous herbage; and the five predominating grasses ranged from about 61½ to about 68¼ per cent. of the total produce. In four out of the six cases the free-growing and bulky Dactylis glomerata was the predominating grass, contributing in one case 31 per cent., and in the case of the smallest amount of it nearly 22 per cent. of the total produce. In the two other cases, the Avena pubescens and A. flavescens, in about equal proportions, predominated, amounting together to from 18 to 19 per cent. In two out of the four cases where Dactylis predominated (Plots 13*a* and 13*b*) a very excessive amount of ammonia-salts was employed; and in the one case the mineral manure contained silicates, when a considerably larger amount of Agrostis was found in the produce, but whether the result were really due to the supply of the silicates may be a question. In fact, it was in dealing with the very heavy and luxuriant crops that the difficulty of fairly sampling was the greatest; and we would, therefore, especially in such cases, rest our conclusions much more upon the general than upon the exact indications of the figures. Although Agrostis and Holcus, two bad elements, occurred in considerable quantity in the bulky produce of all the highly-manured plots, it is satisfactory to observe that the free-growing and useful Dactylis, the sweet and much-relished Avena pubescens and A. flavescens, the useful Poa trivialis, and the free-growing and nutritive Lolium were all prominent components in these luxuriant crops. Of other grasses, Festuca duriuscula or F. pratensis came next in order of prevalence, the rest occurring for the most part in very insignificant proportions.

Of Leguminous plants these heavy crops in some cases contained scarcely a trace, and in others only very insignificant amounts.

Of Miscellaneous herbage, Rumex acetosa, as usual with full

manuring of any kind, is by far the most predominating plant; Carum Carui and Achillæa millefolium coming next in order. All others, Ranunculus and Plantago included, occurred in very small amounts; and the total quantity of Miscellaneous herbage, which was small, was attributable chiefly to the luxuriance of the Rumex and the Carum, and the frequency of the Achillæa millefolium.

III.—*The tendency to the Development of leafy or stemmy Produce, and the Order of Ripeness.*

As already explained, in the separations of 1858, the results of which were recorded in our former Report, the Graminaceous herbage was classified into "Stems bearing flower or seed," which could be referred to particular species, and into "Detached leaf and indeterminate stems;" and hence the figures pretty directly indicated the relative tendency to the production of stem and seed, or of leaf. But since in the recent separations all the detached leafy matter that could be identified is included, with the stemmy portion, under the head of "Determined species"—the remainder only being put down as "Undetermined stem and leaf," or "Shedded flowers and seeds, &c."—the numerical results of the present inquiry do not serve to illustrate the subject of the tendency to the development of leafy or stemmy produce. The figures in the column in Table II. showing the amounts remaining as "Undetermined stem and leaf" do indeed indicate, where the amount is large, that the separation and identification were unusually difficult, and so far generally that the produce was leafy and ill-defined rather than stemmy and matured; but in the few remarks we have to make on the point in question, as well as on that of the relative ripeness, we shall rely on careful observations made on the ground just before and at the time of cutting, in which ten conditions or orders of ripeness of the produce (of the 20 plots) were noted.

The unmanured plots presented a very thin crop of stem, with a full and uniform development of leaves, which were, however, very short, affording upon the whole a pretty even and close, but meagre bottom herbage, which was green and late at the time of cutting, its order of ripeness being No. 8. Leguminous and Miscellaneous plants were numerous, but mostly of stunted growth.

Superphosphate of lime alone gave a crop very much like the unmanured one as to general relation of leaf and stem, &c., but it was rather more luxuriant, and showed more tendency to the production of fine leaf, chiefly belonging to the smaller and later

grasses; it contained much less Leguminous herbage, nearly the same proportion of Miscellaneous plants, and was somewhat more matured at the time of cutting, its order of ripeness being No. 6.

Mixed mineral manures alone gave a very equally maturing and generally ripe crop, but with only a small proportion of the more grossly growing grasses; the finer ones, however, mostly flowering or seeding. Leguminous plants were very numerous and luxuriant, but few of the Miscellaneous ones were so. Order of ripeness No. 2.

Ammonia-salts alone gave a very green and unripe crop, the order of ripeness being No. 10. There was a dense bottom herbage, with the foliage coming chiefly from the root, and very little flowering tendency. Upon the whole the grasses, which were for the most part of the smaller kinds, seemed but partially developed, apparently exhausted, and not likely to mature. Lolium perenne showed the most tendency to form stem and seed, but was frequently monstrous or dying.

Nitrate of soda alone gave a crop which at the time of cutting was very late, dark green, and still growing, without the look of exhaustion exhibited by the herbage grown by ammonia-salts alone; it was much more leafy than stemmy, forming a dense mass of grassy produce, for the most part referable to the smaller-leafed species; and, as the amount of undetermined stem and leaf will show, the separation and identification of its components were unusually difficult. The order of ripeness was No. 9.

Farmyard-manure alone yielded a produce which was, upon the whole, comparatively ripe, standing 4th in this respect, but it was very unequally so. All the grasses gave a fair proportion of stem, and they were also generally plentiful in both base and stem-leaves. Poa trivialis and Bromus mollis were the predominating grasses, but there was a fair proportion of most of the others found on the unmanured land, the grosser species being, however, somewhat restricted in development.

Farmyard-manure and ammonia-salts, like farmyard-manure alone, gave a very unequally ripe crop, which also in order of ripeness was No. 4. Its characteristics were great luxuriance, a fair proportion of both stem and leaf, and a considerable variety of herbage; but with Poa trivialis, Dactylis glomerata, and Bromus mollis, by far the most prominent species among the grasses, giving upon the whole a strong and thick-bottomed, but rather rough crop.

With superphosphate of lime and ammonia-salts the crop was much more backward than with superphosphate of lime alone, coming 10th instead of 6th in order of ripeness. There was,

relatively, much less development of stem and much more of leaf, forming a strong and luxuriant bottom-grass, of a dark-green colour.

The mixed mineral manure and nitrate of soda gave crops which were very much riper, especially where the double amount of nitrate was used, than those by nitrate of soda alone; the order of ripeness was with the smaller amount of nitrate (and minerals), No. 5, and with the larger amount, No. 1; the crops with nitrate alone standing 9th, and those with the mixed mineral manure alone 2nd. There was, however, a great tendency to the production of leaf, the stems being somewhat thinly distributed.

The mixed mineral manure in conjunction with ammonia-salts, as with nitrates, greatly enhanced the production of stem and the ripening tendency. The crops grown by this combination—which were the heaviest in the series—were very luxuriant, and still vigorously growing at the time of cutting, the grosser species of grass predominating. There was a very full development of both stem and leaf; the foliage, however, coming in larger proportion than usual from the stem. With the smaller amount of ammonia-salts the crops were 4th in order of ripeness; but with the larger amount they were only 7th, being later, greener, and more vigorously growing, and showing a greater abundance and luxuriance of Dactylis glomerata.

In connexion with the results brought out in this inquiry into the action of special manures on the mixed herbage of grass-land, it will be interesting, at the present time, when the subject of the utilisation of *town sewage* is so much discussed, to call attention to the prominent characters of the herbage developed when it is applied to permanent meadow land.

In some experiments conducted during the last two years by the Royal Sewage Commission, and still in progress, on the application of the town sewage to grass land at Rugby, it is found that effects have resulted very similar to those recorded in this paper. The prevailing grasses on the unsewaged land were Dactylis, Holcus, Lolium, Festuca, Agrostis, Poa, and Avena; a number of others occurring in smaller proportion. Of the sewaged produce, by far the largest proportion consists of Dactylis, Holcus, and Lolium; whilst Festuca, Agrostis, Avena, Poa, and other grasses, are far less prominent than in the unmanured produce. Under the influence of sewage too, the Leguminous herbage is found to be almost excluded; and the Miscellaneous weedy plants are very much reduced in variety, though some few are very much increased in luxuriance, among which Rumex, Ranunculus repens, and sometimes Taraxacum, are the most prominent.

In the well-known Edinburgh sewaged meadows again, the herbage is for the most part of a very simple character. Of the grasses, the most prominent, and the most valued for its yield of green food, is the Poa trivialis; next in prevalence, and perhaps in general estimation also, is the Triticum repens, or couch grass; and after these, frequently occur Lolium perenne and Dactylis glomerata. Of weedy plants, the Ranunculus seems to be the most prevalent and luxuriant, especially where the drainage is imperfect. It should be observed, however, that many of the Edinburgh meadows have been laid down specially with a view to sewage irrigation; though, where old permanent meadows have been brought under treatment, or a considerable mixture of grasses has been sown in laying down for irrigation, it is still found, after a few years, that the great bulk of the herbage is composed of but a few of the freer growing grasses.

It will be readily understood, however, that the value of the produce of ordinary permanent meadow land, and of a sewage-irrigated meadow, depends upon very different qualities, and that a character of growth which may be a disadvantage in the one case, may be advantageous in the other.

The produce of the ordinary meadow, if designed for hay, is allowed to approach nearly to maturity before being cut, and over luxuriance of growth, tending to the great predominance of a few very free growing grasses, is likely to be accompanied by an undue development of woody stem, giving a hard, coarse, and comparatively indigestible and innutritious food. There is, in fact, an obvious limit beyond which it is not advantageous to go in forcing the hay crop by means of artificial manures; for, beyond a certain point, which the intelligent practical farmer will not be slow in discerning, not only is less increase of produce obtained for a given amount of manure employed, but the increased quantity is gained at too great a sacrifice of quality.

It is quite otherwise with the sewage-irrigated meadow, the produce of which is to be cut green. Although it may happen that only the very free growing (and under some circumstances objectionable) grasses may be encouraged, yet they are mown in a young and succulent condition, before their objectionable qualities have been developed, and the faster they grow the oftener they are cut. Hence, whilst their great luxuriance is only an advantage, their tendency to yield a hard later growth is not against them.

The most prominent results of the whole inquiry may be briefly enumerated as follows:—

1. So far as the general distribution of Graminaceous, Legu-

minous, and weedy herbage, and the tendency to the production of leafy or stemmy produce, and to early or retarded ripening are concerned, the characters of the produce of the seventh season of the experiments (1862) are, in the main, similar to those before recorded of the produce of the third season, 1858; but there is considerable change in the relative predominance of certain species on particular plots. Dactylis glomerata, Festuca duriuscula or F. pratensis, Avena pubescens or A. flavescens, Poa trivialis or P. pratensis, and Alopecurus pratensis, have, respectively, become much more prevalent on one or more of the plots, according to the description of manure employed.

2. The *unmanured* produce consisted of 74 per cent. Graminaceous, 7 per cent. Leguminous, and 19 per cent. weedy herbage. It showed great variety, and comparatively little predominance of individual species. Festuca duriuscula and F. pratensis, and Avena pubescens and A. flavescens, were the most prominent; whilst the freer growing grasses were in smaller amount, and a number of others in less proportion still. The crop was even, but very short, and with little development of stem: and it was green, and comparatively late, at the time of cutting.

3. *Mixed mineral manures alone* gave comparatively little increase of Graminaceous herbage, and reduced the proportion in the produce, both of it and the weedy herbage; but they greatly increased both the amount per acre, and the proportion, of the Leguminous plants, Trifolium, Lathyrus, and Lotus. The description of the Graminaceous herbage was not very much altered from that of the unmanured land; there was no striking predominance of individual species, but, compared with the produce by more productive manures, a pretty even mixture of most of the grasses occurring without manure, and those which did show any prominence were chiefly of the smaller and less free-growing kinds. The tendency to form stem and seed, and to early ripeness, was much greater than without manure.

4. *Ammonia-salts alone* considerably increased both the amount and proportion of the Graminaceous herbage, almost excluded Leguminous plants, and generally reduced the number and amount of Miscellaneous or weedy species, but much increased the luxuriance of some, particularly Rumex acetosa, Carum Carui, and Achillæa millefolium. The relation to one another of the Graminaceous species, as to amount, was much the same as without manure, excepting that Festuca duriuscula and Agrostis vulgaris were brought into much greater prominence. The increased growth was characteristically that of root or base-leaves, and there was very little tendency to form stem or to ripen.

5. *Nitrate of soda alone*, like ammonia-salts alone, considerably increased the produce of Graminaceous herbage, and tended chiefly to the production of root-foliage. The nitrate, however, strikingly brought into prominence the Alopecurus pratensis, at the expense, compared with the produce by ammonia-salts, chiefly of Agrostis vulgaris, and partly of Festuca duriuscula. Otherwise, the distribution of species was not very materially altered, the more luxuriantly-growing grasses not being much developed. The crop was much more leafy than stemmy, very dark green, and late; contained very little Leguminous herbage, though rather more than the produce by ammonia-salts alone; and the weedy plants were luxuriant rather than numerous—Plantago lanceolata, Centaurea nigra, Rumex acetosa, Achillæa millefolium, Ranunculus, and Taraxacum, all being more or less encouraged.

6. *The combinations of nitrogenous manure* (ammonia-salts or nitrates) *and mixed mineral manures*, gave by far the largest crops, the largest proportion of Graminaceous herbage, the largest proportion referable to a few species, scarcely a trace of Leguminous plants, and a small proportion both in number and amount of Miscellaneous or weedy ones. The produce was very luxuriant, with a great development of stem and stem leaves, and a much greater tendency to ripen than when the ammonia-salts or nitrates were used without the mineral manure. The predominating grasses were the most bulky and free-growing ones; Dactylis glomerata, and Poa trivialis, being very prominent; and Avena pubescens or A. flavescens, Agrostis vulgaris, Lolium perenne, and Holcus lanatus, somewhat so. Festuca duriuscula, F. pratensis, Arrhenatherum avenaceum, Alopecurus pratensis, Bromus mollis, and others, were almost excluded.

7. *Farmyard-manure* considerably increased the growth of the grasses, and of some few weeds, particularly Rumex, Ranunculus, Carum, and Achillæa, and reduced that of clover and allied plants, more especially when used in combination with ammonia-salts. It greatly encouraged the growth of the good grass Poa trivialis, and of the bad one Bromus mollis; and when in conjunction with ammonia-salts the Dactylis glomerata. Under both conditions Festuca duriuscula and F. pratensis were nearly excluded, and Avena flavescens, A. pubescens, Agrostis vulgaris, Lolium perenne, and Arrhenatherum avenaceum, were very much reduced. The crops were upon the whole bulky, comparatively simple as to description of herbage, fairly luxuriant both in stem and leaf, somewhat rough and coarse, and showing a tendency to unequal ripeness.

8. *Leguminous herbage* was almost entirely excluded whenever nitrogenous manures were used in any quantity, whether in the form of ammonia-salts or nitrates, alone or in combination with mineral manures; but it was somewhat less so with the

nitrate than with the ammonia-salts. Mineral manure alone, containing both potass and phosphoric acid, greatly increased the growth of the Leguminous plants perennial red clover and meadow vetchling. Farmyard-manure like artificial nitrogenous manures, also, but in a less degree, much diminished the proportion of the Leguminous herbage.

9. Every description of manure diminished the number of species, and the frequency of occurrence, of the *Miscellaneous* or *weedy herbage;* mineral manures alone less so than any other; nitrogenous ones, especially in combination with mineral constituents, did so very strikingly, but they at the same time greatly increased the luxuriance of a few species, especially Rumex acetosa, and frequently Carum Carui and Achillæa millefolium. Plantago and Ranunculus were generally discouraged by active manures, excepting farmyard-manure and nitrate of soda. The nitrate also favoured Centaurea nigra and Taraxacum Dens-leonis.

10. Considerable increase of produce was only obtained by means of farmyard-manure, or artificial manures containing both mineral constituents and ammonia-salts or nitrates. The crops so obtained were much more Graminaceous, and consisted in much greater proportion of but a few species of plants. The grasses developed were chiefly of the more bulky and freer growing kinds, and the produce was generally very stemmy—being the more so, and the coarser, the more excessive the manuring.

11. Meadow-land mown for hay should not be manured exclusively with artificial manures, but should receive a dressing of well-rotted farmyard dung every four or five years.

12. Sewage irrigation, like active manures applied to meadow-land in the ordinary way, has also a tendency to develop chiefly the Graminaceous herbage, excluding the Leguminous, and to a great extent the Miscellaneous or weedy plants. It also, at the expense of the rest, encourages a few free-growing grasses, among which, according to locality and other circumstances, Poa trivialis, Triticum repens, Dactylis glomerata, Holcus lanatus, and Lolium perenne have been observed to be very prominent. The result is an almost exclusively Graminaceous and very simple herbage. But, as the produce of sewage-irrigated meadows is generally cut in a very young and succulent condition, the tendency which the great luxuriance of a few very free-growing grasses has to give a coarse and stemmy later growth is less objectionable than in the case of meadows left for hay.

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